

2008

# Test Targets 8.0: A Collaborative effort exploring the use of scientific methods for color imaging and process control

Robert Chung  
rycpr@rit.edu

Bill Pope

Fred Hsu

Franz Sigg

Evan Anderson

*See next page for additional authors*

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## Recommended Citation

Chung, Robert, Bill Pope, Fred Hsu, Franz Sigg, Evan Andersen, Jiayi Zhou, Khalid Husain, Michael Riordan, Test Targets 8.0, A collaborative effort exploring the use of scientific methods for color imaging and process control. Rochester, NY: RIT School of Media Sciences, 2008. <https://scholarworks.rit.edu/books/71>

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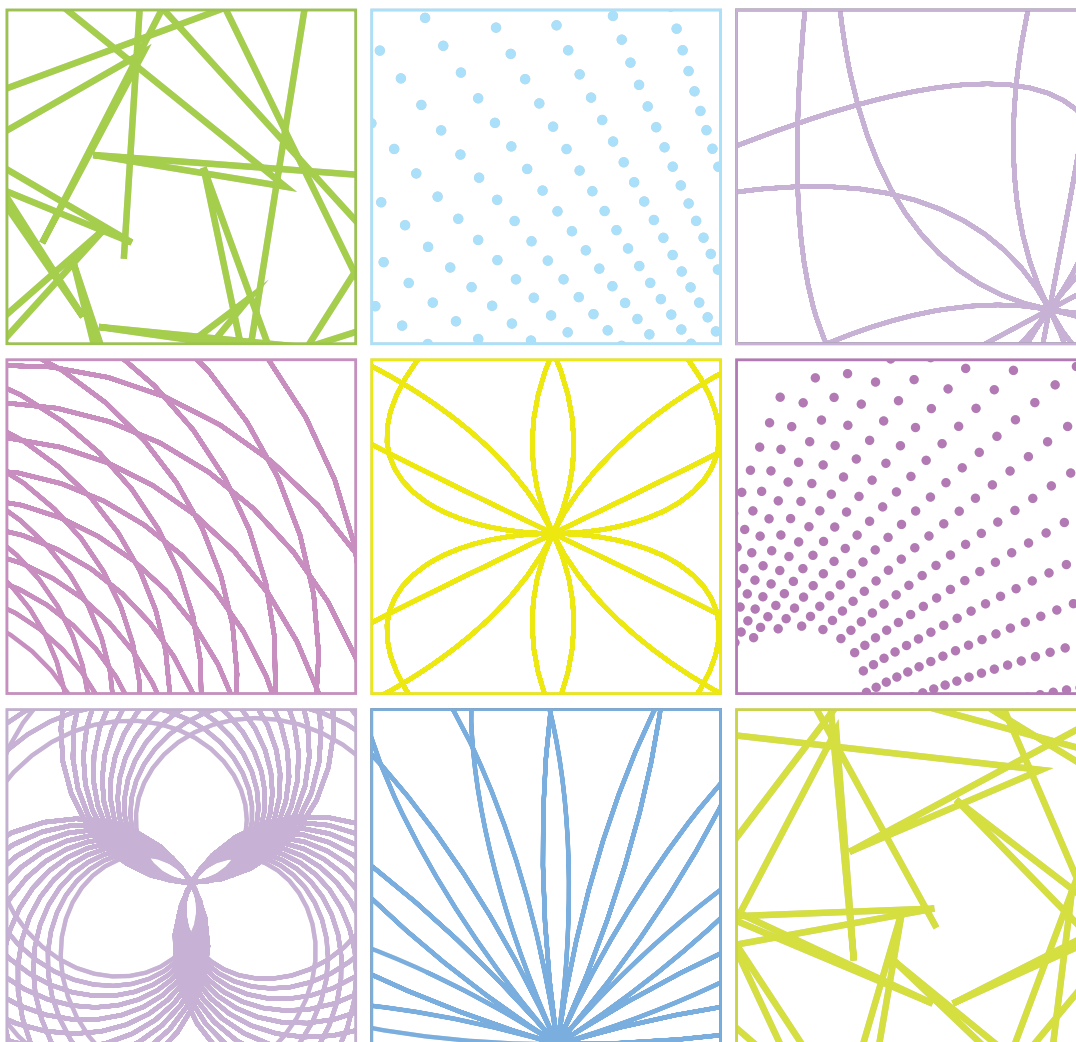
**Authors**

Robert Chung, Bill Pope, Fred Hsu, Franz Sigg, Evan Anderson, Jiayi Zhou, Khalid Husain, and Michael Riordan

# Test Targets

R-I-T School of Print Media Publication 8.0

A collaborative effort exploring the use of scientific methods for color imaging and process control



Published by R-I-T School of Print Media  
November 2008

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Printed at RIT in Rochester, New York, USA



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# Test Targets, An Introduction

## From Content Creation to Digital Asset Management

Robert Chung  
rycpr@rit.edu

### Keywords

publishing, digital asset, data security

### Abstract

Publishing is both a journey and a destination. In the case of *Test Targets*, the act of creating and editing content, paginating and managing digital assets, represents the journey. The hard copy is the result or destination that readers can see and touch. Like the space exploration program, everyone saw the spacecraft that landed on the moon. It was the rocket booster that made the journey from the earth to the moon possible. This article portrays the process of capturing ideas in the form of digital data. It also describes the process of managing digital assets that produces the *Test Targets* publication.

### 1.0 Introduction

There are two significant changes in the world of publishing. The first change is about tools used for writing. We used to write our thoughts down and draw figures with pencils and paper. Today, we write and draw with a microcomputer, a drawing program, and a word processor. The second change is about tools used for publishing. Before the days of microcomputers, tools used for publishing, e.g., typesetters, process cameras, were in the hands of journeymen and professionals. Today, these publishing tools are in the form of software packages, e.g., Adobe InDesign, Photoshop, Illustrator, and designed for microcomputer users.

*Test Targets* is an annual publication by the School of Print Media, Rochester Institute of Technology. It provides print media students and faculty members the opportunity to journey through various tasks from content creation to digital asset management with emphases on scholarship, aesthetic, and print production.

### 2.0 Technical Content Creation

The journey of transforming original ideas into a well-written paper begins with an author or authors. If the author is a student, he/she would have taken two or more courses in printing process control and color management. A final lab project from a higher-level course often serves as a starting point. The experiment may be refined and the paper rewritten with more depth and references cited.

Technical papers, submitted as Microsoft Word files, are peer reviewed. A co-op student coordinator was instrumental in carrying out the double-blind review process. Both internal reviewers (RIT faculty members) and external reviewers (industry experts) were asked to offer a decision to either accept or reject the paper. They are also asked to make comments and changes in the Word document via the "Track Change" feature. The coordinator then forwards reviewer's comments and the Word File with track change to the authors for revision. Revised manuscripts are then ready for editing. Finally, the peer-reviewed, revised, and edited manuscript becomes the contents for publishing.

Early versions of *Test Targets* contain only technical reports on process control and color management. Today, colorful visuals are included in the section, Gallery of Visual Interest, to add visual appeal to the technical material.

The Test Form section of *Test Targets* is a collection of useful test patterns with known input contents, e.g., standard CMYK characterization chart, Total Area Coverage chart, pictorial color reference images, etc. Starting from, we include a brief description regarding what each test form is and its key features.

## 2.0 Graphic Content Creation

Cover design and section head design also add to the aesthetic dimension of the publication. Tom Chung, an art director of an advertising agency in New York City, designed the first two issues of the cover. Later, we tried to encourage printing students to submit cover designs. We also tried to design the *Test Targets* cover by a committee of technocrats. None of the above creative processes is desired or long lasting.

Searching for a better cover design solution, *Test Targets 8.0* sought design input from RIT computer graphic design students. We asked graphic design faculty members to critique the submission. Members of the *Test Targets* team then singled out the cover design by voting. Indeed, it is much easier to vote for a good design than to create one! The cover design style is also used to create graphics for section heads in the publication.

## 3.0 Digital Asset Management

As a writer, he/she generates a digital file when writing something new. The writer then stores the document on a hard disk. This being the simplest case, the writer needs to know where the file was stored and how to retrieve it in order to edit it or share it with others. So, imagine for a moment that *Test Targets* authors are writing their papers from different locations. These files are stored and, later on, accessed by others for review, comment, editing, proofing, and prepress. Having the ease of accessibility and information security becomes essential.

We used to manage data files with the use of a sneaker-net and a multi-gigabyte hard disk. Now, we have password-protected Internet-based servers. In order to keep the accessibility and security of data intact, we need to address the digital asset management issues, i.e., where to store the assets and who has access to them.

Two separate servers are used to store *Test Targets* data. The first is the CIAS server, accessible by *Test Targets* team members on campus using their RIT computer accounts. It contains work-in-progress documents of *Test Targets 8.0*. The server also hosts digital assets of past issues of *Test Targets*. As a rule, we leave the legacy files locked. We would repurpose the file, update its content, and save it as a new file.

The second server is the Internet-based Xinet, accessible by registered users anywhere and anytime. It contains files that can be downloaded for peer review, and files or review feedback for uploading. It also contains final digital files, with strict naming conventions, for prepress operations. Both servers perform routine backup of all files to prevent data loss.

## 4.0 Summary

*Test Targets*, whether as a journey or a destination, has given us challenges, excitement, and rewards. It gives us a platform to practice what we teach and learn in the classroom. It motivates us to push the limits of our technical competency to a new height. We're the equivalent of fuel, consumed by the rocket booster, which pushes the space ship to its destination. In the end, it allows us to witness the effect of synergy and collaboration where one plus one plus one is greater than three. Indeed, *Test Targets* combines the disciplines of scholarship, graphic design, and digital asset management together. What a ride this has been. Oops... What a great lesson this has been.

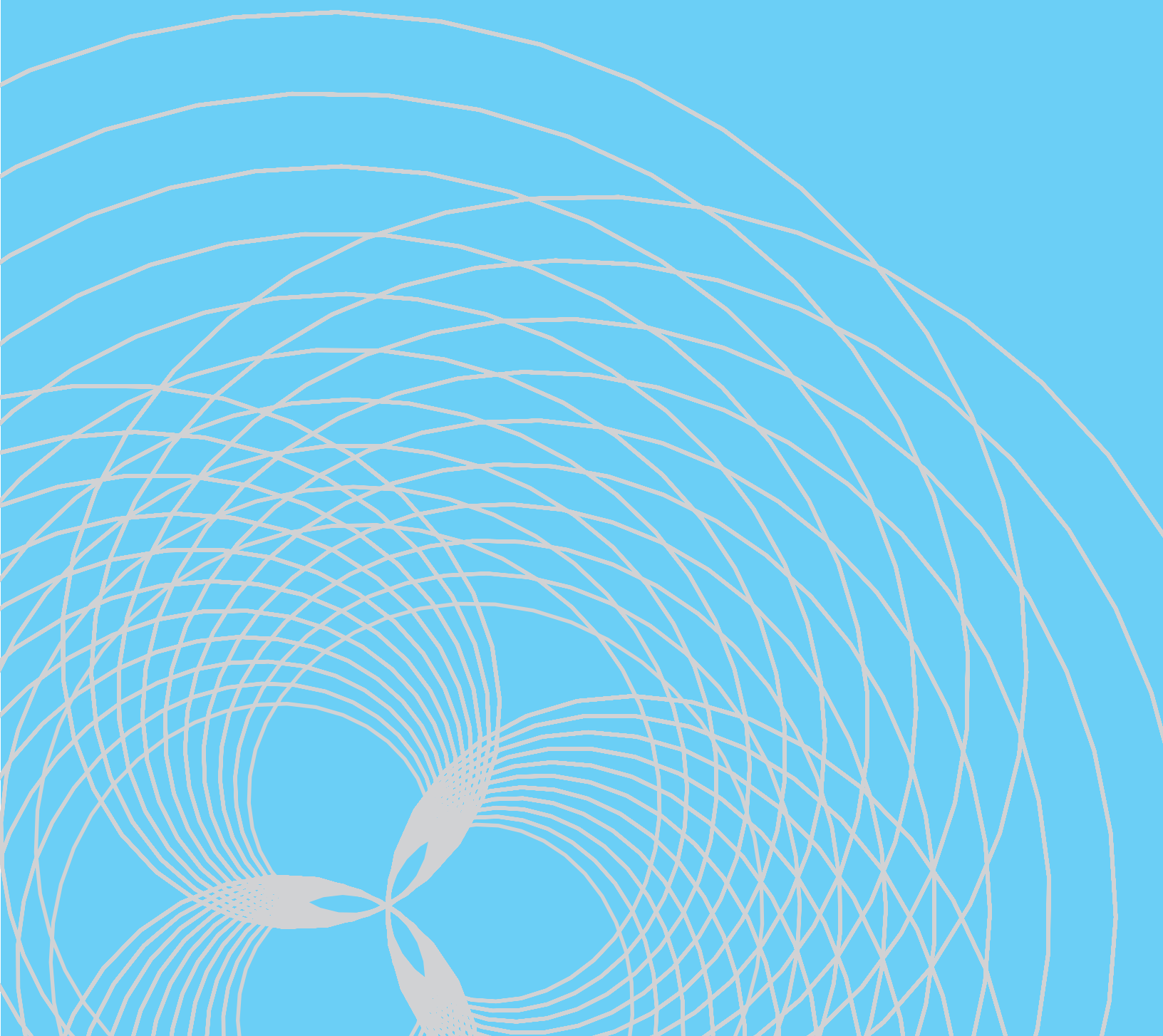


### *Journey of Digital Files of Test Targets 8.0*

The journey of a published article in *Test Targets 8.0* typically travels through several stages: (1) as digital files in the hands of the author, (2) as a paginated InDesign file with links, (3) as an InDesign Book file, (4) as a PDF, (5) as an imposition file for output. To elaborate, manuscripts received from authors are in the form of texts, charts, tables or images, and digital media used at this stage are usually Microsoft Word, Excel, jpg, and tiff files. Before flowing content into an Adobe InDesign document, an InDesign template has been created with the desired page appearance. In addition, digital contents, such as tables and charts, have to be properly corrected for printability and pictorial images converted for color accuracy. Thus, a finalized article, after extensive review and revision, not only has correct content, but also visuals properly prepared and linked in the InDesign document. These separate InDesign files are merged into a single InDesign book according to an imposition plan. The Test Targets project coordinator then submits both the InDesign file and its PDF to prepress of the Printing Applications Laboratory. If the PDF preflights successfully, the offset portion of the job is ready for CTP to support the Heidelberg sheet-fed offset press run and the digital printing portion of the job is ready for the HP Indigo 5500 digital press.

(submitted by Jiayi Zhou)

# TECHNICAL PAPERS



FYI

*Test Target 8.0 Editorial Process*

The editorial process for *Test Target 8.0* involved external and internal reviews. A double-blind external review procedure was used for the first time. Each technical paper was reviewed by two anonymous (to the author) external subject matter experts. The comments received from external readers were used by the author to revise the article that was then ready for in-house editing. The editorial process ended with final proofreading and sign-off.

(submitted by Edline Chun)

# Effect of Ink Sequence on Offset & Digital Printing

Evan Andersen  
eta6520@rit.edu

## Keywords

Ink sequence, ink trapping, offset, digital

## Abstract

ISO 12647-2:2004 for process control in offset lithography standardizes the chromatic ink sequence to CMY. The standard defines black as either first or last, but both are considered acceptable. This fact has prompted the research interest to investigate the effect of the black (K) ink sequence on process color printing and bring some clarity regarding ISO 12647-2:2004.

Color matching between offset and digital printing is desired and often expected in the marketplace, yet, different ink sequences and trapping behaviors are observed between the two. Assuming that a digital file has been prepared for offset printing, the questions arise, “Will a digital press produce matching color to an offset process if printed with the same file?” and, “What is the effect of ink sequence on each process?”

This project examines how the two ink sequences of CMYK and KCMY differ for both offset and digital printing. A test form was created and printed using a Heidelberg Speedmaster 74 sheet-fed offset press and an HP Indigo 5500 digital press. Response analysis of density and CIELAB values of overprints were conducted, as well as visual and ICC-based color gamut analysis.

It was concluded that there is measureable as well as visual difference between both ink sequences for offset and digital printing, though minimally significant. Due to wet ink trapping in offset, printing K last, has a tendency to produce less maximum density (Dmax) and gamut volume than printing K first, though inconsistent results occurred. The digital press, without these trapping issues, behaving differently than offset, consistently produced more Dmax and a larger gamut volume when K was last.

## 1.0 Introduction

In the printing industry today, tradition and the notion of printing as a craft are both still valid, though the concept of printing by the numbers and standardization is more typical. In regards to offset ink sequence, it is commonplace to print CMY, as standardized by *ISO 12647-2:2004 Graphic technology—Process control for the production of half-tone color separations, proof and production prints-Part 2: Offset lithographic processes*. However, the opinion

of K first or last is one of mixed conviction. There are some who favor K last while others say the opposite that wet ink trapping of offset printing creates lower contrast and Dmax. Who is right? Can there be one answer that fulfills the diverse needs of printers? Whether K first or last matters or not, it is important to simply understand the effect of ink sequence on color and image quality to allow for repeatable and predictable results.



## 2.0 Objectives

The ink sequence of CMY has been standardized and well practiced for offset printing, though the placement of black ink is optional. Also, as digital technology continues to improve, the expectations of digital printers producing a facsimile to offset has increased. These points have driven the following research interests, which stand to examine (1) what the effects of changing ink sequence from K first to last in offset printing are, and (2) what the effects of changing ink sequence from K first to last in digital printing are.

## 3.0 Methodology

To properly examine the effects of ink sequence on each process, customized test forms were needed. The test target used to examine the effects of ink sequence on color and image quality was designed by Gary Field (2004), and Franz Sigg from the Rochester Institute of Technology (*Test Targets 6.0*, 2006). The topics addressed are: (1) design of the ink sequence target, (2) printing of each target, (3) verification of ink consistency across the target by densitometry, (4) analysis of the overprint patches of both K first and K last, and (5) analysis of gamut volume and visual differences of pictorial test images.

### 3.1 Ink Sequence Test Target

In *Test Targets 6.0*, an ink sequence target was designed by Gary Field and Franz Sigg (shown in Figure 1) to test how changing the sequence of K (first to last) would affect offset printing. That press run, two years ago, did not consider ink tack, leaving a variable unaccounted for and thus warranting this present press test. The target has solid patches and overprints of C+K, M+K, Y+K, CM+K, CY+K, MY+K & CMY+K and is printed with both K first and K last. Although the target is the main area of interest, the test form also accompanied two



Figure 1. Ink sequence test target

pictorial test images for visual assessment of the effects, an IT8.7/3 target for printer characterization and color bars for process control.

### 3.2 Printing the Test Forms

For each press run a custom test form was created to maximize the page real estate and meet the specifications of each printer. The sheetfed offset run was printed with a tack sequenced ink set, allowing a lower-tack ink to always be laid down onto a higher-tack grade. The tack values used on the Heidelberg Speedmaster 74 sheet-fed offset press (SM74) press run were: Black 1st down-17.4, Cyan-13.8, Magenta-14.4, Yellow-12.2, and Black 5th down-11.0. With two separate black ink stations, both ink sequences could print in one pass. A high-tack black was in the first ink station and a low-tack black in the fifth. On the digital press run a much smaller test form was required, and ran separately for each desired ink sequence. The functionality of the HP Indigo 5500 digital press (HP5500) allows for in-line ink sequence changes without clean up or change over time.

### 3.3 Verifying Printing Consistency

To verify that the same solid densities were obtained on the ink sequence target, density values of the solid C, M, Y, and K patches were measured. The K measurements were made from the black bar along the target. Five density readings were made and averaged to give an approximate measure. Assuming the values are within tolerance, this would show that any further change seen through testing would be due to a change in ink sequence and not density or printer variability.

### 3.4 Overprint Analysis

The overprint patches, with K either first or last, were measured using an X-Rite 530 spectrodensitometer to obtain density and colorimetric data ( $L^*a^*b^*$ ) and  $\Delta E_{ab}$  values were computed. These differences show the quantitative color difference due to the changes in ink sequence. Furthermore, the 21 darkest patches of the IT8.7/3 target were also measured and compared between sequences to better understand the dark shadow region where the effect was localized.



### 3.5 Gamut Analysis and Visual Difference

To better understand the significance of the measurements on the solid overprints, the color gamut was also evaluated. Using an Eye-One ISis spectrophotometer, the IT8.7/3 printer target was measured and a profile created with Gretag-Macbeth ProfileMaker 5.0. These profiles were viewed using a 3-D graphing tool and the gamut volumes were computed with CHROMiX ColorThink. Additionally, visual comparisons of test images were made between both ink sequences and press runs.

### 4.0 Results and Analysis

Below are the findings of this project with discussion relative to ink sequence and comparing offset to digital printing. The main areas of interest in analyzing the ink sequence test forms were density, to verify ink consistency, color ( $L^*a^*b^*$  values) of overprint patches with computed  $\Delta E_{ab}$  and  $L^*$  analysis of the 21 darkest patches, gamut volume; and visual comparison.

#### 4.1 Comparing K First vs. Last for SM74

*Density:* Table 1 shows the average density values of five measurements from each set of solid patches on the SM74 ink sequence target.

Table 1. Density values of SM74 solid patches with computed  $\Delta D$

SM74 Density Verification			
Patches	K First	K Last	$\Delta D$
C	1.28	1.21	0.07
M	1.43	1.40	0.03
Y	1.03	1.02	0.01
MY	1.53	1.51	0.03
CY	1.54	1.51	0.06
CM	1.30	1.24	0.04
K	1.43	1.39	0.02
CMY	1.46	1.44	0.02

The density difference ( $\Delta D$ ) of the K solid ink densities was found to be a minimal 0.02. Additionally, the largest  $\Delta D$  was found to be 0.07, which is based on the max filter density. It can be stated that the printed density of the ink sequence target is consistent throughout. From here onward, it

will be assumed that any changes between K first and last (on the SM74) are because of ink sequence and not density or printing inconsistency.

*Color:* Table 2 shows the measured colorimetric data of the SM74 ink sequence target with computed  $\Delta E_{ab}$ . Changing the ink sequence from K first to last resulted in an average color difference of 6.6  $\Delta E_{ab}$  with significant variation of 12.1 and 12.0 in the MY+K and Y+K overprints. These inconsistent and larger changes when K was interacting with Y may have occurred due to poor wet ink trapping between K and Y. The offset printing process lays wet ink on top of wet ink, which results in what is called: wet "ink trapping," the percent of ink that lies over the top of another. Wet ink trapping is considered a factor because of the large increase in  $L^*$  for those two patches when K was last (the patches got lighter with K on top of Y versus below). Furthermore, the measurements show that K first on the SM74 produced lower  $L^*$  than K last, meaning darker shadows.

*Gamut Volume:* To better understand the significance

Table 2. Colorimetric values of SM74 overprints with computed  $\Delta E_{ab}$

SM74							
Patches	K First			K Last			$\Delta E_{ab}$
	L	a	b	L	a	b	
C+K	15.9	-5.4	-11.0	16.3	-5.9	-8.8	2.2
M+K	13.5	14.5	1.4	14.9	13.8	-3.8	5.4
Y+K	18.4	-2.5	11.3	26.4	-2.4	20.3	12.0
MY+K	12.8	9.6	5.4	17.0	20.3	9.3	12.1
CY+K	15.0	-12.5	4.7	18.6	-18.6	8.4	7.9
CM+K	11.0	7.1	-6.8	11.6	4.1	-9.8	4.3
CMY+K	10.6	0.3	1.1	11.7	1.4	0.1	1.9

of the overall color difference, a gamut volume was computed using CHROMiX ColorThink software. Table 3 shows the gamut volumes for both K first and last for the SM74 press run. For the SM74, K first has produced a larger gamut than K last.

Table 3. Gamut volume of SM74 ink sequences K first and last

SM74 Gamut Volume	
CMYK	376,129
KCMY	384,251

These numbers are computed based on the grid points within the profile and there is only a 2.12% difference between the two. This variation can also be stated as 98% of the larger gamut (KCMY) is defined within the smaller. Since the only portion of the sequence that is changing is K, the differences in gamut are localized to the dark shadows. The common CMY gamut between the two sequences is the same; the dark colors are where any objective and subjective differences will occur.

*Visual Comparison:* The visual analysis was conducted by comparing the two test images within the printed test form. The first image was highly chromatic making it negligible due to the lack of K, and shadows. The second image was a neutral portrait of a bride and groom. This image features shadow detail in the tux, but minimal to no difference was perceived between the two.

#### 4.2 Comparing K First vs. Last for HP5500

*Density:* Table 4 shows the average density values of five measurements from each set of solid patches on the HP5500 ink sequence target.

Table 4. Density values of HP5500 solid patches with computed  $\Delta D$

HP5500 Density Verification			
Patches	K First	K Last	$\Delta D$
C	1.42	1.40	0.02
M	1.46	1.45	0.01
Y	0.98	0.97	0.01
MY	1.68	1.70	0.02
CY	1.51	1.52	0.01
CM	1.38	1.39	0.01
K	1.60	1.61	0.01
CMY	1.53	1.55	0.02

Similar to the SM74, the  $\Delta D$  of the K solid ink density was a minimal 0.02; this was also the largest difference, which leads to the assumption that the ink density is consistent across the target. Any changes between K first and last (on the HP5500) are assumed to be due to ink sequence and not to density or printing inconsistency.

*Color:* Table 5 shows the measured colorimetric data of the HP5500 ink sequence target with com-

puted  $\Delta E_{ab}$ . Changing the ink sequence from K first to last resulted in an average  $\Delta E_{ab}$  change of 7.1 with significant variation of 10.1, 11.0 and 9.7 in the CMY+K, CM+K, & MY+K overprints. These resulting color differences for the HP5500 press run show that even on a dry-on-dry printing process, the alteration of ink sequence affects the output. In digital printing (specifically for the HP5500), dry toner particles are laid on top of already cured toner, with what is considered a 100% ink trap. The measurement data shows a consistent decrease in  $L^*$  when K was last, thus producing darker shadows than K first.

Table 5. Colorimetric values of HP5500 overprints with computed  $\Delta E_{ab}$

HP5500							
Patches	K First			K Last			$\Delta E_{ab}$
	L	a	b	L	a	b	
C+K	11.1	-6.1	-9.5	11.6	-6.9	-7.6	2.1
M+K	14.3	13.9	3.0	10.2	11.8	-2.0	6.9
Y+K	18.3	-4.7	7.9	15.7	-1.1	10.0	4.9
MY+K	17.1	4.9	6.7	10.1	9.7	2.2	9.7
CY+K	14.5	-11.8	1.9	10.6	-8.4	1.7	5.2
CM+K	12.5	7.5	1.1	7.4	2.2	-5.8	10.1
CMY+K	16.7	-0.1	4.9	8.1	0.7	-1.8	11.0

Ink transparency could be a factor, with seeing darker  $L^*$  values when K is on top of the chromatic inks; possibly the black ink is preventing light from passing down, fully, through the other inks.

*Gamut Volume:* To better understand the resulting color difference for the HP5500 press run, Table 6 shows the gamut volumes for each ink sequence. For the HP5500, K last has produced a larger gamut than K first.

Table 6. Gamut volume of HP5500 ink sequences K first and last

HP5500 Gamut Volume	
CMYK	384,845
KCMY	369,128

The HP5500 press run exhibited a 4% difference between the sizes of each gamut. With such a minimal difference, there are few colors not able to be rendered by both ink sequences. Figure 2

shows a 3-D representation of these two gamuts plotted together. The white wireframe represents the larger CMYK gamut, and the colorful shape it encases is the KCMY gamut. This graphical representation of the volumes in Table 6 gives a visual of the minimal color difference and specifically the localization of these differences in the dark shadow region of the gamut.

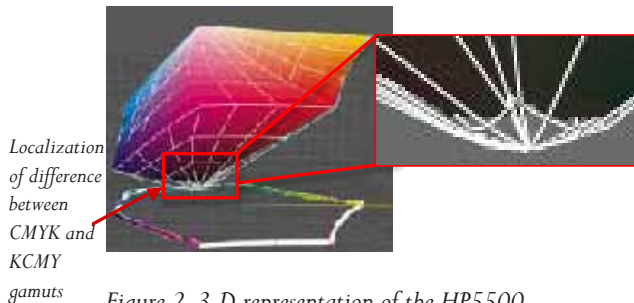


Figure 2. 3-D representation of the HP5500 CMYK and KCMY color gamuts

*Visual Comparison:* When comparing the neutral, wedding test image (Figure 3), there are small differences in the visual max density, and color of the shadow areas, and as expected, the skin tones and white dress are alike. Figure 3 shows a close-up of the tuxedo within the wedding test image, and differences are seen with K last producing slightly more visual contrast and a faint color variation.

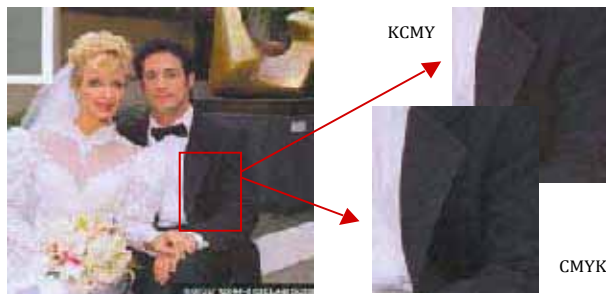


Figure 3. HP5500 test image visual comparing the difference in KCMY (top) and CMYK (bottom)

### 4.3 Comparing the Differences between SM74 & HP5500

In comparing the two processes of offset and digital, there are certainly differences that affect the output of each. When trying to produce alike images between the two, these differences are obstacles that must be understood to achieve good

results. Analyzing both ink sequence test forms show that both processes do exhibit changes in density, colors, and gamut. In the HP5500, it is clear that K last produces a darker  $L^*$  and larger gamut. The changes in ink sequence for the SM74 produced a more variable effect, with an overall larger gamut when K was first.

### 5.0 Conclusion

Examining both SM74 and HP5500 ink sequence targets show similar results, in that an overall color change of approximately 7.0  $\Delta E_{ab}$  occurred when changing the K ink sequence between CMYK and KCMY. Visually this change was not as significant with the test images used, which is explained by the gamut volume and 3-D graphing shown in both Tables 3 and 6, as well as Figure 2. With only a 2% and 4% difference in gamut size, localized to the dark colors/shadows (low  $L^*$ ), the majority of the gamuts will be rendered accurately by both ink sequences. Any visual difference perceived, particularly in the HP5500 will be in dark colors. This magnitude of difference is seen in Figure 4 with  $\Delta L^*$  differences of 8.26 in the HP5500 and 3.61 in the SM74.

Figure 4 shows a closer analysis of the dark portion of the gamuts with computed  $\Delta L^*$  between K first and last. Focusing in on the 21 darkest  $L^*$  patches with common CMYK values from the IT8.7/3 target (with CMYK as a reference); the positive values are a result of the K last sequence

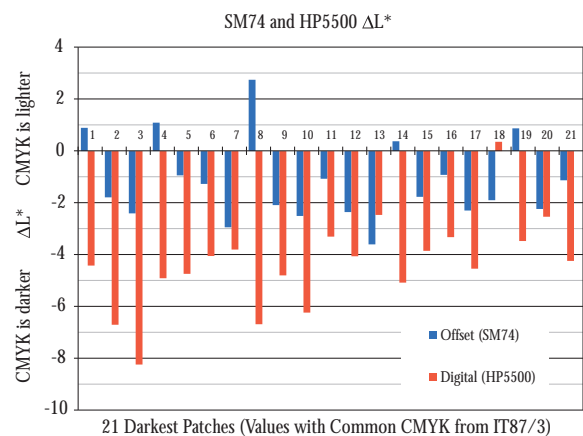


Figure 4.  $\Delta L^*$  for the darkest  $L^*$  values between CMYK and KCMY ink sequences.

producing a lighter  $L^*$  and the negative values are a result of K last producing a darker  $L^*$ . The plot shows a greater and more consistent measure of CMYK being darker on the HP5500, and a lesser, more inconsistent measure, for the same, on the SM74.

This graph first makes clear the effect of ink sequence on the HP5500, with consistent darker shadows (max  $\Delta L$  of 8.2) in K last. Second, it shows the variation present in the SM74 results. Earlier, by measuring the K+Y and K+MY overprints patches, it was found that K first produces darker  $L^*$ , but those measurements were not representative of the average. Here the 21 darkest patches show an average with CMYK as darker but with some variance on the opposite side. The CMYK values for those positive plots (CMYK is lighter) were examined but no patterns were found to suggest wet ink trapping as a factor. Therefore, this variation is not fully understood, but still clearly present.

When it comes to the placement of black ink, which is the correct decision? Can there be one solution or standard ink sequence that accounts for K first or last? Due to the slightness in visual difference, a new or revised standard may not appear necessary. However, it is more important to be consistent in the procedures used, and if the need arises to change sequence, small color and density changes should be expected. Understanding the effect of ink sequence is important, as it could allow for better results in match between the two processes (there are other variables as well, such as their different colorants). For offset, K first results in slightly more density and larger gamut, and for digital, K last produces those same findings. Referring back to the research interest, and based on the findings, it does not appear necessary to change the standardized ink sequence presently in ISO 12647-2:2004 for process color printing in offset lithography.

## 6.0 Acknowledgments

I would like to first thank Gravure Research Professor Robert Chung for his involvement and encouragement in this research and compiling of the results. I would also like to thank Senior Research Associate Franz Sigg for his work in designing and creating the ink sequence test target and form. Also, I would like to thank Professor Gary Field, the visionary for this project. It has been his desire to seek an answer to the questions surrounding ink sequence and his relationship with Professor Chung that allowed this project to start back in Test Targets 6.0. I had the chance to meet Gary Field and his passion for research and discovery was encouraging; I am grateful for the experience. I lastly would like to thank all involved in the Test Targets publication, for I know they have worked hard and long to put all of this together.

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# Predicting Spot-Color Overprints

## A Quantitative Approach

*Khalid Akhter Husain*  
*kah2227@rit.edu*

### Keywords

spot colors, lookup table (LUT), trapping, spectral models, predictability, overprint, portability, color management

### Abstract

This paper investigates two methods to predict the spot-color overprints for a given set of colorants: 1) using ICC based lookup tables and 2) a mathematical model based on spectral data.

Two spot-color test targets for two ink sets were printed, by lithography and by a digital printing process, and the spectrum of the colorants was measured. The measured reflectances were then utilized to create an n-channel ICC profile using X-Rite GregtagMacbeth's ProfileMaker. The spectral reflectance measurements of the solids were then also used to explore a spectral based model which also uses the following parameters: ink trap, a way to estimate the transparency of the second ink, and a measure of mechanical and optical dot gain.

The mathematical model shows an acceptable level of accuracy in predicting spot-color overprints. The color difference between the predicted and measured spot-color overprint was found to be less than  $4 \Delta E_{ab}$ .

### 1.0 Introduction

Spot colors are special colors and not part of process set CMYK. The spot colors, for instance, are defined by the Pantone system as swatch books or color library plug-ins found in Adobe Creative Suite and they are available as printing inks. Some advantages of spot colors for printing application are: (1) to obtain more colors that are outside the gamut of process colors; (2) for brand identification in packaging applications; and (3) since a single color is required it is easier to maintain the color consistency on the press rather than maintaining the color balance between four process colors.

Today, spot colors find their place in many packaging and wall covering applications. For process colors, the ICC color management system works because it is based on actually printed targets that sample the whole color gamut. When using

spot-color overprinting, obtaining color profiles is complicated as there are more than 1,000 spot colors available. For a graphic designer to predict the appearance of a two spot-color overprint, he or she would first have to print a profiling target, which is impractical.

Today's PostScript-based premedia software does not understand or support the use of multi-channel separation and transparency and flattens or knockouts the overprint when the image is processed (Prakhya & Chung, 2008). The graphical software applications do not provide an accurate representation of spot-color interaction, from design to display and to print. In technical words, the spot-color system lacks color management infrastructure.

There are mathematical models that can predict the appearance of spot-color overprints. For these

equations to work they have to know some printing variables such as trap, ink sequence, transparency, dot gain and spectral information of each ink used. Having the correct inputs to the mathematical model reduces errors in predicting the color of the overprints. In this report, preliminary results obtained by both the ICC-based method and mathematical model for predicting the spot color overprints are explored.

Companies such as Sun Chemicals have introduced their own proprietary digital color library via a SmartColour plug-in in Adobe Photoshop. This software uses spectral data, which can predict the tints and the solid overprints of two or more colorants. This proprietary profiling software uses a complex mathematical model to generate and simulate the print process with the specified inks on the given substrate to the printed production (Sharma, 2008). However this software was not used for this report.

## 2.0 Objectives

The objective of this paper is to evaluate two methods available for predicting overprints colors. The study is intended to assess the accuracy of the ICC-based LUT (Lookup Table) method, and to evaluate a spectral-based model to predict reproduction of spot color and their overprints.

## 3.0 Literature Review

Research done by Prakhya and Chung (2008) on predicting the spot-color overprints points out the failure of today's available premedia software in communicating the true color of spot-color overprints. Their article deals with soft proofing, and conducts an evaluation of display-to-print match of the spot-color solids and their overprints with a change in ink sequence. The study shows that there is a void in the color management workflow for spot colors because of the missing link between the device-to-PCS (A-to-B).

Viggiano (1990) examined a mathematical model to predict the combination of colored halftone patterns. His paper discusses the Neugebauer color mixing model and the Yule-Neilson model to predict the tints

from its solid. The paper pointed to the importance of the effect of ink trapping when two ink dots are partially overlapped on top of one another.

Viggiano and Prakhya (2008) discuss how the different trapping models can estimate the overprint. The paper also discusses the importance of subadditivity failure that needs to be taken into account when studying the ink trap. Subadditivity is related to transparency of an ink. It is caused by scattering of light in an ink layer

## 4.0 Methodology

Two sets of Pantone spot colors 1788C (red)-7466C (turquoise) and 599C (green)-493C (pink) were used for this research. The rationale behind using these colors was to investigate the overprint prediction for both high and low chroma colors. These same colors were used by for the research done by Viggiano & Prakhya (2008) and Prakhya & Chung (2008).

The red and turquoise inks were printed on a Heidelberg Speedmaster 74 for both ink sequence. The test charts printed used nominal dot area percentages of 0, 25, 50, 75, and 100% for each primary color, resulting in a 25-patch chart. Because the printing was performed wet-on-wet, only one sequence was expected to trap well, because of the tack sequence. The tack value of the inks used was provided by the ink manufacturer and shown in Table 1. The other set represents 100 patches of two-color overprint with nominal dot area percentages of 0, 20, 30, 40, 50, 60, 70, 80, 90, and 100% for each primary color. These sets of patches were printed on an HP Indigo 5500 (dry-on-dry). The same procedure was repeated for offset for the pink and green inks.

*Table 1. Tack value of the inks specified by the manufacturer*

Pantone spot-color # (coated)	Tack Value
1788 (Red)	13
7466 (Turquoise)	12
493 (Pink)	12
577 (Green)	11.5

The 25 patches target was generated and measured using X-Rite/GretagMacbeth's Measure Tool, which allows the user to set the amount of colorants and the ink sequence used. The printed target was measured with a GretagMacbeth Spectrolino Spectroscan spectrophotometer using 0/45 geometry measuring the spectrum from 380nm to 730nm at 10nm intervals, without a UV-cut filter. The spectrum of the colorants measured is in terms of absolute (non-zeroed-on-paper) reflectances. Once the target is measured, the reflectance spectrum of the different solids and overprints and the unprinted substrate, are collected in an Excel spreadsheet where all analysis is done.

The spectral reflectances will be converted to colorimetric values to create an ICC profile using ProfileMaker's Multichannel option that can create n-color profiles. The profile created is inspected using Profile Editor.

Using the Yule-Neilson model and Hamilton's trapping model, both the tint values and the 100% overprints can be predicted from the solid spectral curves.

To determine how the two inks interact when overprinted, the following parameters were measured: percent trap, tack and transparency for offset inks, and densitometric and colorimetric parameters. For offset inks, the saturation density of the second-down ink was measured using an Eye-One Pro spectrophotometer for the ink film thickness of approximately 2 mm. After the measurements and computations, the data were analyzed and evaluated by means of graphical analysis. The printed hardcopies were used as the reference to evaluate the accuracy of the mathematical model.

#### 4.1 Lookup Table Approach

This section describes the ICC-based workflow using the LUT approach. Most ICC printer profiles work in the CMYK colorspace, but in this case, profiles that would deal with more than just CMYK are needed. Such profiles are identified as "n-channel" or "multi-channel." Each special color

combination requires its own new target to create the profile.

The ICC workflow uses three profiles: the input source profile, the display or monitor profile, and the output profile (Sharma, 2003). The ICC workflow converts the input device dependent color space to corresponding points in device independent color space, called the profile connection space (PCS). The CIELAB color space is used as the standard color space for the PCS. The LUT uses a complex interpolation method that maps the input color to the nearest PCS color value available in its database. The ICC profiles do not contain any spectral data or colorant parameters, but contain CIELAB values to predict the color rendition of CMYK printing devices (Sharma, 2003). The monitor is just like an output device. Monitor profile is obtained through its calibration, which contains a lookup table connecting the PCS (CIELAB) color space to the monitor color space (RGB).

To use profiles with spot colors, a plug-in by GretagMacbeth is required for PhotoShop to convert an RGB or CMYK original to spot-color separations. The flow chart shown in Figure 1 displays the processes and resources involved in the LUT-based approach.

#### 4.2 Spectral-based Model

This section describes how to determine the spectrum of an overprint of halftone colorants using the parameters of colorants and substrate. Besides the spectral curves of the solids and substrate, there are four other parameters that need to be considered: trap, transparency, n-factor and mechanical dot gain.

The spectral-based method uses the Neugebauer equation modified by Yule-Neilson and Hamilton's trapping model to predict the color of halftones and the 100% overprint respectively. The spectrum of the printed overprint is not used in the model, but is needed to verify the accuracy of the model.

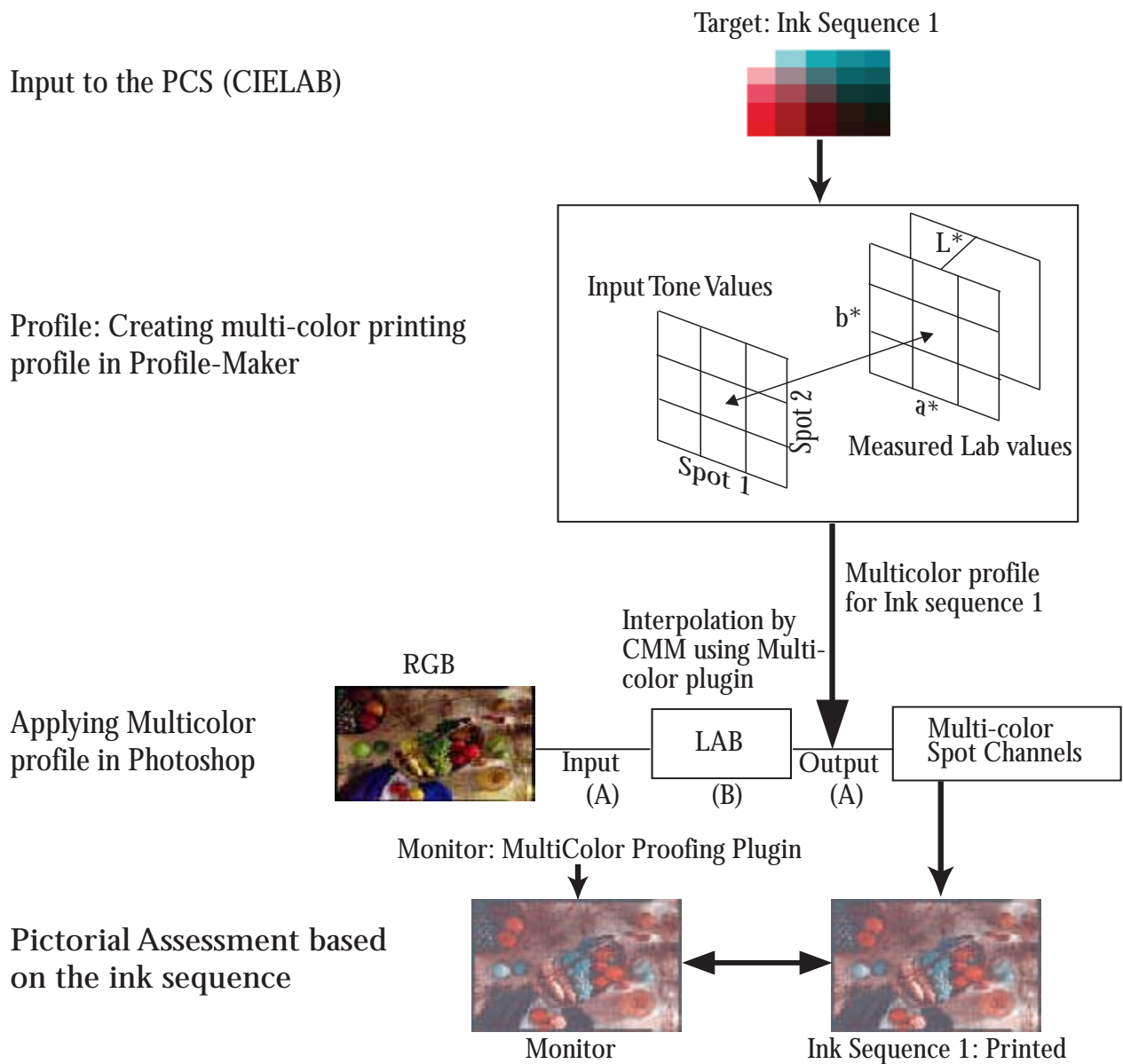


Figure 1. The flowchart representing the process for ICC-based approach

The model for predicting appearance of colors for a halftones printing process was first introduced by Neugebauer in 1937. The model is based on additive color mixing of the partial areas that result when overprinting the dots of the printing inks as shown in Figure 2.

Figure 3 represents the density spectrum of two inks and the substrate. Interestingly, the overprint density is less than the second ink down density in the red region between 590 nm-700 nm. This is probably caused by trapping.

#### 4.2.1 Neugebauer Model and Yule-Neilson Model for Colored Halftones

The spectral Neugebauer model predicts the reflection spectrum of a color halftone patch as the sum of the reflection spectra of its individual colorants (Neugebauer primaries) weighted by their fractional coverage area and the substrate (Vigiano, 1990). Figure 3 shows the Neugebauer primaries of a two spot color tint that relate to the Demichel's halftone dot areas on the paper. The equation is expressed symbolically as:



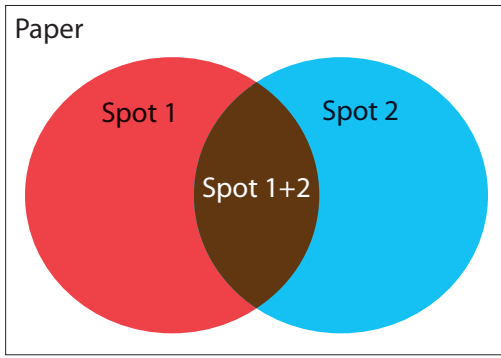


Figure 2. Neugebauer primaries for two color overprint

$$R(\lambda) = \sum_{i=1}^{2^N} w_i R_i(\lambda) \quad (\text{Eq.1})$$

$w_i$  = relative area for each primary as calculated by Demichel equation  
 $R_i$  = reflectance of the primary at each wave length

Therefore for two-color overprint, there will be  $2^2 = 4$  Neugebauer primaries, which are assumed to be mixed additively: one containing paper only; two which contain one ink; and one which contains both inks.

The Neugebauer color-mixing model fails to account for optical dot gain that is caused by internal reflection at the paper surface. Yule-Neilson, in 1951 proposed a correction factor for the Murray Davis equation for this effect by using an  $n$ -factor to improve the model accuracy. In 1985 and 1990, Viggiano applied the Yule-Neilson relationship to the spectral Neugebauer equation, yielding the Yule-Neilson modified Spectral Neugebauer model. The model can be referred to as Viggiano-Yule-Neilson-Neugabauer model and is defined as:

$$R(\lambda) = \sum_{i=1}^{2^N} \{w_i R_i(\lambda)^u\}^n \quad (\text{Eq.2})$$

$n$  = Yule-Neilson factor  
 $u = 1/n$

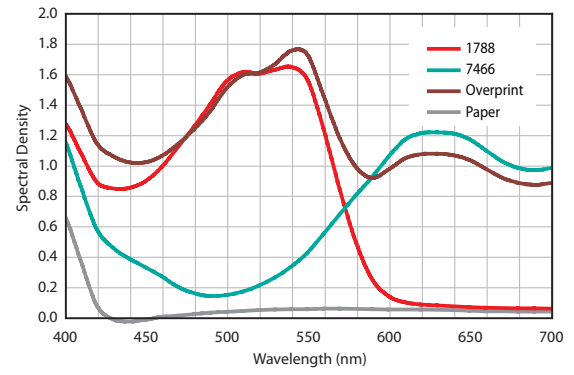


Figure 3. Density spectrum of an overprint: first-down ink (1788), second-down ink (7466)

For a two spot-color overprint, Equation 2 can only predict the spectrum of the overprint tints if the spectrum of the overprint solid is known. Therefore (in the absence of a printed profiling target), another equation is needed to predict the spectrum of the two spot-color solid overprint. There are two variables that affect the color of an overprint: trapping and transparency.

Trap indicates how much of a colorant sticks to an underlying colorant that is previously printed (Viggiano & Prakhya, 2008). In 2008 Viggiano and Prakhya examined various trapping models for predicting the overprint. They re-cast Hamilton's trapping model to predict overprint spectra, and found, for the cases they considered, that it did so accurately. Their re-arrangement of Hamilton's trapping model to predict overprint spectra is expressed as:

$$D_{12}(\lambda) = D_{2\infty, \lambda} - (D_{2\infty, \lambda} - D_{1, \lambda}) \left[ \frac{D_{2\infty, \lambda} - D_{2, \lambda}}{D_{2\infty, \lambda} - D_p, \lambda} \right]^{T_h} \quad (\text{Eq.3})$$

$D_{12}$  = spectral density of the overprint  
 $D_1$  = spectral density of first ink down  
 $D_2$  = spectral density of second ink down  
 $T_h$  = Hamilton's trap  
 $D_{2\infty}$  = saturation density of the second-ink down  
 $D_p$  = density of the unprinted substrate

While developing and verifying the model, the spectral reflectances of the solids, tints, and the overprint are readily available from a print.

The saturation density is needed to determine the transparency of the second ink down. According to Davidson (1969), the saturation density is a point at which the optical density no longer increases as the ink film thickness is increased. A simple way to understand the concept of transparency is by simply looking at the color of the ink in the ink can. If one can see the actual color of that ink, then the ink is considered to be opaque and hence the saturation density will be same as the density of that ink when printed at normal ink film thickness. If the color of the ink in the can is darker or black from the printed color, then the ink is considered to be transparent as all the light incident on the ink gets absorbed by the pigment. In this case the saturation density is very high compared to the density of the printed ink. Transparency is not just a constant, but varies with wavelength.

Therefore it is possible to evaluate the transparency on the basis of practical measurements. This is not the case for trapping, because to actually

measure trapping for the two color overprints we would require an actually printed two color overprint. There are two solutions to this dilemma: 1) making an educated guess of the trap value (based on the tack of the individual inks) and hope that this is good enough for a first approximation; 2) try to find the correlation between the trap and the tack on the basis of experiments. Option 2 is beyond the scope of this report. All that is attempted at this time is to show that if we had the correct input value for the trap, then the equation gives an accurate prediction of the spectral curves of an overprint. So the question is how do we find the correct input value for the trap. Since, for the development of the equation, we have the printed target and therefore know the spectral curve of the overprint color, we can use an iterative approach to find which trap value would give the best agreement between the measured and the calculated spectral curve of the overprint.

The flowchart shown in Figure 4, displays the process and the input parameters involved in the prediction of the spot-color overprint spectrum for the spectral-based model.

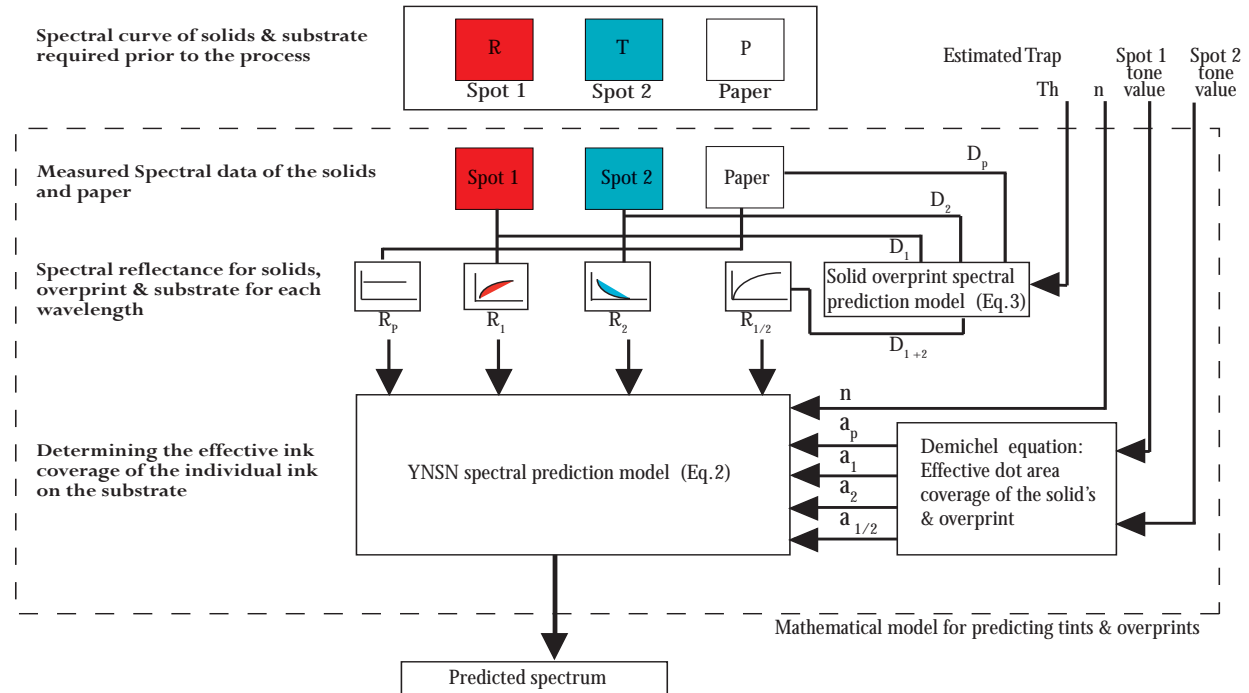


Figure 4. The flowchart representing the method for predicting spot-color overprints using spectral-based model

## 5.0 Results

### 5.1 Measurements of Printed Spot-Colors and Their Overprints, for Different Printing Processes and Ink Sequences

Profiling targets were printed on both Heidelberg SM74 and HP Indigo 5500 using both ink sequences for both ink sets (Pantone1788 (red) – 7466 (turquoise) & Pantone 493 (pink) – 577 (green)). The spectral reflectance of the two ink sets was measured with a GretagMacBeth SpectroScan spectrophotometer. Figure 5 shows the differences in the color when the ink sequence is changed. The 3-D gamut plot displays the color differences between the two ink sequences, the color of the arrow is a function of magnitude in terms of  $\Delta E_{ab}$ . The green arrows indicate  $\Delta E$  of less than 2, yellow arrows indicate  $\Delta E$  of less than 4, and the red arrows indicate large color differences with  $\Delta E$  of more than 4. Further investigation shows that the change in the ink sequence does not affect the paper white and the single solids reproduced, but does affect the two color tints and solid overprints. It can be observed from the printed results that the color produced with 1788 as the first-ink down has more chroma compared to the color produced when 7466 is the first-ink down. Similar test forms are included in this Test Target book on pages 66-67 and pages 70-71.

Figure 6 shows a comparison between the two-color overprint measurements when printed dot-on-dot, i.e., on HP Indigo 5500. It can be seen from the 3-D gamut plot that the color difference between the two sequences is minimal compared to the wet-on-wet process, since there is a minimal effect due to trapping in digital printing, as the colorant printed is dried before the next colorant is applied on top.

Figure 7 displays a 3-D gamut plot for the other set of inks used, i.e., 577C-493C. Compared to Figure 5, the overall colors reproduced are less than a  $\Delta E_{ab}$  of 4. Also the change in the ink sequence does not have much effect on the solid overprints. As noted, the color gamut with the 1788-7466 ink set is larger compared to the color gamut of 577-493 ink set.

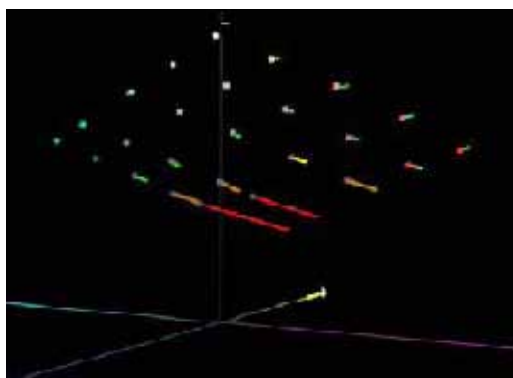


Figure 5. 3-D gamut plot of two spot-color overprint sequences printed wet-on-wet. The vector tail represents the first ink sequence (Red as first ink down) and the vector head represents the second ink sequence (Turquoise as first ink down)

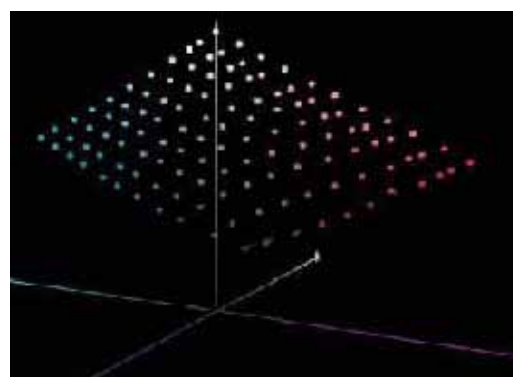


Figure 6. 3-D gamut plot of two spot-color overprint sequences printed dry-on-dry. The vector tail represents the first ink sequence (Turquoise as first ink down) and the vector head represents the second ink sequence (Red as first ink down)

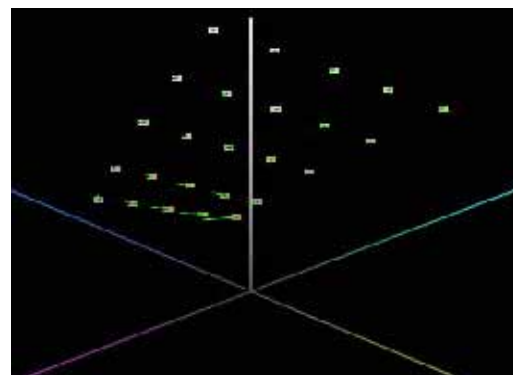


Figure 7. 3-D gamut plot of two spot-color overprint sequences printed wet-on-wet. The vector tail represents the first ink sequence (Pink as first ink down) and the vector head represents the second ink sequence (Green as first ink down)

Table 2 lists the  $\Delta E_{ab}$  color differences for the change in the ink sequence for both ink sets.

Table 2. Color differences of Offset inks between the ink sequence.

	Inks	Tone Value	$\Delta E_{ab}$
Offset	1788-7466	50	2.42
		100	25.80
	577-493	50	0.79
		100	4.88
HP Indigo	1788-7466	50	0.73
		100	3.7

## 5.2 Testing GretagMacbeth MultiColour Plug-In

The color separations for pages 66-67 and pages 70-71 were done using the MultiColor Separation

Plug-In. The soft proofing preview did not appear to match the printed colors very well, but this could be because we have not yet applied the MultiColor Proofing Plug-In correctly.

## 5.3 Spot-Color Reproduction Using Spectral-Based Model

Figures 8 and 9 show the spectral density curves of the solid overprints for both sequences and both ink sets, comparing the measured and calculated response.

It can be seen from both graphs that the differences are small. The saturation densities used in the equations come from real measurements of the inks. The n-value was arbitrarily fixed at 2 and mechanical dot-gain was assumed to be zero, the digi-

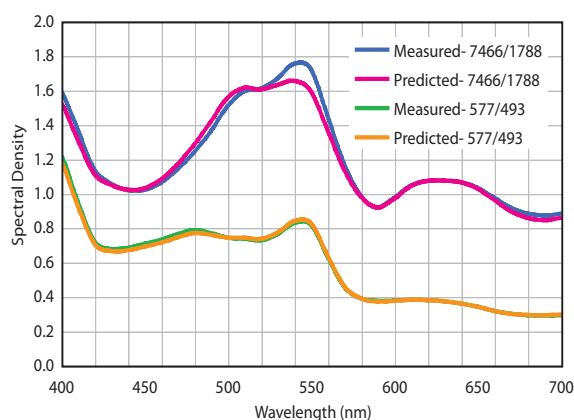


Figure 8. Measured and Predicted overprint spectra: Turquoise over Red & Green over Pink

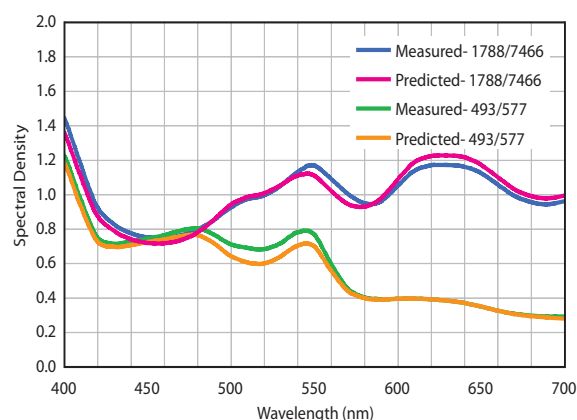


Figure 9. Measured and Predicted overprint spectra: Red over Turquoise & Pink over Green

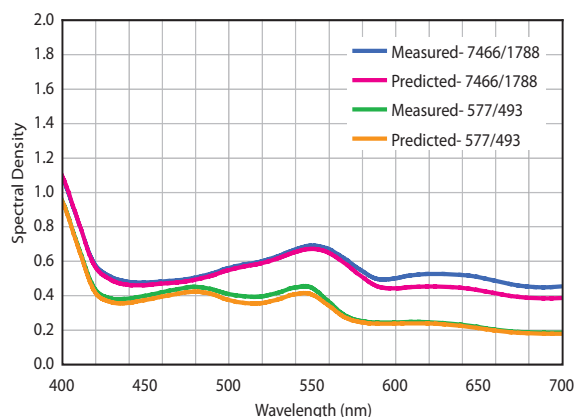


Figure 10. Measured and the Predicted spectra for 50% tints: Turquoise over Red & Green over Pink

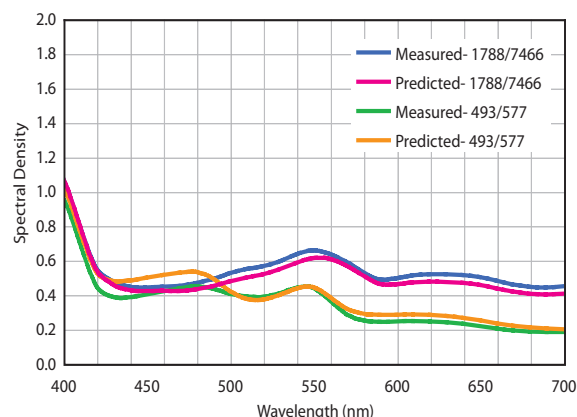


Figure 11. Measured and the Predicted spectra for 50% tints: Red over Turquoise & Pink over Green

tal or PostScript dot size was used. The trapping values were obtained through iteration for each ink set and sequence. Theoretically the trap values are lower with incorrect tack sequence (Viggiano, 2008). It is seen that the trap difference for high chroma ink sets (Red and Turquoise) is larger compared to the low chroma inks (Pink and Green).

Figures 10 and 11 display the predicted and measured spectra using the Yule-Neilson colored halftone model when overprinting 50% halftone tints. Table 3 displays the trap based on the ink sequence.

Table 3. This table shows the trapping values, for each overprint combination. The overprint with reverse tack sequence are indicated by \*

R over T*	T over R	P over G	G over P*
0.43	0.81	0.66	0.58

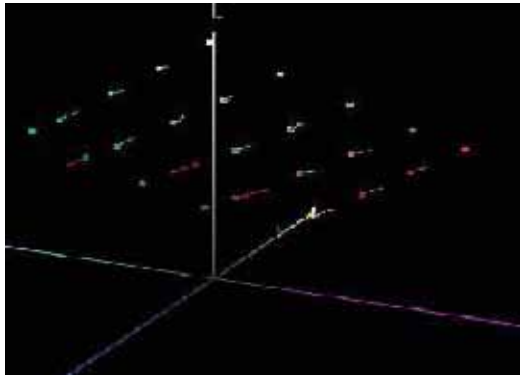


Figure 12. 3-D gamut plot of t25 predicted samples using spectral-based model. the vector tail represents the predicted colors and the vector head represents the measured colors

Table 4. CIELAB total color difference  $\Delta E_{ab}$  between the measured and the predicted spectral response

Ink Sets	Sequence	Tone Value	$\Delta E_{ab}$
Set 1	T over R	50	4.7
		100	2.27
	R over T	50	1.36
		100	1.39
Set 2	P over G	50	1.7
		100	1.39
	G over P	50	1.83
		100	3.07

## 5.4 Plot of Measured and Predicted Overprint Gamut

The 3-D gamut plot shown in Figure 12 represents the predicted colors relative to the measured colors. The prediction errors are probably mainly due to the under estimating of mechanical dot gain, thereby overestimating the spectral reflectance factors. Table 4 shows that the iterated  $\Delta E_{ab}$  color differences between the measured and the predicted value for both ink sets using the spectral-based model are less than 4.

## 6.0 Summary & Conclusion

For the Lookup Table method the following is required: 1) A profiling target is generated using the GretagMacbeth Measure Tool; 2) This target is printed and the measurements are used by Profile Maker to create the multi-color profile. In order to apply this profile to an image the MultiColor Plugin from GretagMacbeth is required in Photoshop to convert the image to multi-channel. To display this multi-channel file in true colors on the monitor, or to optimize it for a proofing system, it is necessary to use the MultiColor Proofing plugin from GretagMacbeth. (See Appendix on pg.17.)

The advantage of an ICC-based multi-channel profile is that the Lab values come from a printed target, which accounts for parameters such as substrate, ink transparency, trapping and dot-gain. Changes in the process, such as a change in ink sequence, require printing of a new profiling target. Each combination of spot colors requires printing of a new profiling target. Therefore, this workflow is not suitable for spot colors in a situation where a graphic designer has to choose between many possible spot colors for a new product, because the number of spot-color permutations is high.

The advantage of mathematical model is that it can be easily adapted to different printing conditions by simply changing parameters in the equations. No printing of test targets is required, except a one time production of a swatch book, and a one time measurement of ink properties such as tack, trap, and ink saturation density. A preliminary test



of the accuracy indicates that a good agreement can be achieved for practical purposes. The needed parameters for the spectral model all come from single color prints, no overprinted colors are required. This is because the spectral-based model uses data from actual colorants characterization and physics which involves only a few input parameters and just the spectral curves of the solid and substrate, no overprints and tints.

The mathematical model discussed in this paper on the basis of preliminary results seems to have the potential to predict the spot color overprints and tints accurately enough (less than 4  $\Delta E_{ab}$ ) for practical applications.

### 7.0 Suggestions for Future Research

This paper investigated the available method to predict spot-color overprints. It is now required to take a step ahead and use more than two-color overprints to test the accuracy of the model. Instead of using the iterative method of optimizing the trap values to find the least  $\Delta E$  color difference, one can find the correlation between the trap value and tack of the ink. It would be also important to investigate the effect of absorption and scattering in the ink layers as proposed by the Kubelka-Munk model.

### 8.0 Acknowledgments

I would like to thank Professor Robert Chung for his willingness to set the objective and the procedure and for encouraging me to take on this task. The help of Professor Franz Sigg and Stephen Viggiano in providing an insight about the topic and the technical discussion, allowed me to understand the key aspects of this research. I would also to thank School of Print Media, Professor Sorce, and Professor Chung for providing funds that made this research possible. Last, but not least, I would like to acknowledge our entire Test Target 8.0 group and PAL for giving this publication a deserving place in field of technical research.

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## Appendix: Using X-Rite's MultiColor Plug-In for Adobe Photoshop 1.2 To Create and Proof Multi-channel Files

### About MultiColor Plug-In 1.2

MultiColor Separation Plug-In creates separations for multi-channel processes. Using this plug-in, one can create up to 10 multi-channel files based on the ink sequence. This MultiColor plug-in gives the user full control to convert Lab, RGB, and CMYK files into multi-channels based on selectable intent and ICC profiles. This plug-in is necessary because Photoshop does not display multichannel files colors in true colors. To display such files in true colors on the screen, MultiColor Proofing Plug-In is required. The proofing plug-in can be used for displaying the preview of the printed result for the press and proofer.

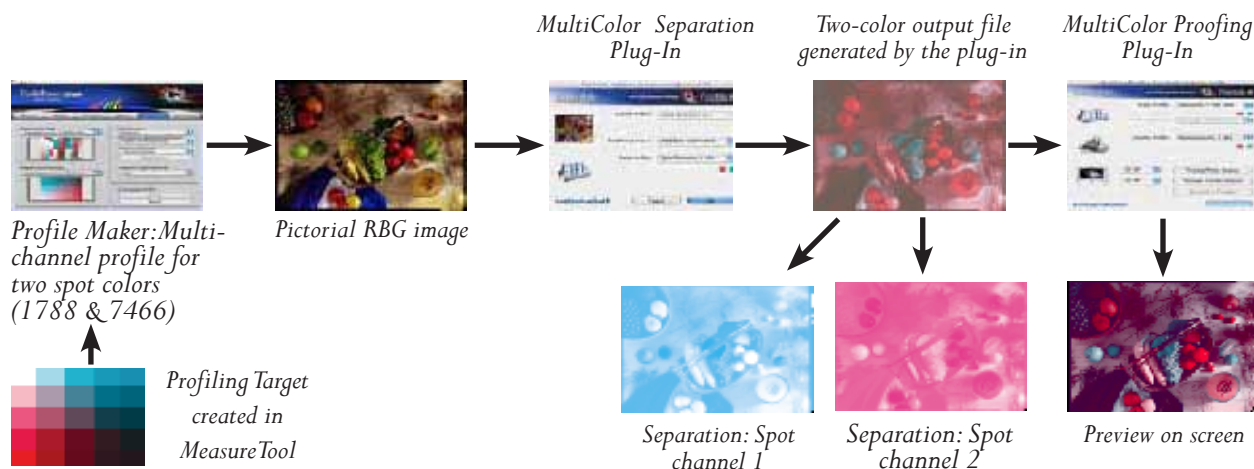
### Profiles in MultiColor Plug-In

MultiColor Separation Plug-In use three inputs: the source profile, the press or the output profile, and the rendering intent. The source profile describes the origin of the file and is used to ensure correct color transformation. If the multi-channel files not have profiles embedded, then one can choose it from the available source profiles. The rendering intent is used to determine the method by which the source gamut is transformed to the press gamut. Relative rendering intent is usually used to achieve highest accuracy in the reproduction and is used for logos. The press profile is used to describe the destination of the printing process for which the data is being optimized.

### Workflow

Creating the multicolor files starts with creating a profiling target using ProfileMaker's MeasureTool. The multi-channel profile is generated using ProfileMaker 5.8. In ProfileMaker there is a option for multicolor, where the user can set the desired rendering intent, profile size, and the light source. The multicolor profile takes into account the ink sequence based on the reference file. Once the profile is created, save it in the ColorSync folder.

Use any RGB, CMYK, or Lab image and apply multi-channel separation using the MultiColor Plug-In in Photoshop. Choose the multichannel profile created in Profile Maker with the desired rendering intent. The plug-in will generate individual separations for each individual ink used. To display the multi-channel file in true colors on the screen, MultiColor Proofing Plug-In is required. Activate the proofing plug-in and choose the required press profile, proofer profile and the rendering intent. Use Preview Press to see the multi-channel files on the screen as they would be outputted in the multicolor process. Preview Proofer is used to simulate the press. The flow diagram below describes the documented process for creating and proofing multi-channel files.



*FYI*

*Color Management in Test Targets 8.0*

Color management encompasses the issue of color portability and intended color image adjustment. Using the group photos in the Colophon section of *Test Targets 8.0* as an example, digital images are captured by a digital camera initially. When digital images are brought to Adobe Photoshop, the color space of an image is converted from the digital camera space to the sRGB working space. Some image-dependent adjustments are necessary to make sure the image looks pleasing in terms of tonal rendering, gray balance, and memory color. The image file is then converted to the printer color space. Three printer ICC profiles, i.e., Heidelberg SM74 CMYK, HP Indigo CMYK, and HP Indigo Multi-Color, are used. The converted image files are paginated in InDesign, output as PDFs, and forwarded to prepress for final CTP or page output. In short, a color-managed workflow must be configured and implemented first before any intended image adjustments.

(submitted by Bob Chung)



# Evaluating Dynamic DeviceLink Profile Performance

Jiayi Zhou  
zxj7306@rit.edu

## Keywords

ICC, color accuracy, color printability, ink saving, simulation

## Abstract

There are two important applications of ICC-based color management technology in the graphic arts industry. The first is the use of ICC device profile that made color portable and reproducible by means of color conversions from any source to any destination color space or color device. The second is the use of device link profile that enhances color printability and predictability. As color management technologies continue to improve, recent dynamic device link technology from Alwan Color Expertise, featuring “Dynamic Maximum Black” algorithms, claims to improve accuracy and consistency of colors with less ink consumption. This paper aims to evaluate and compare the latest Dynamic Maximum Black (Dynamic K) technology with previous Maximum Gray Component Replacement (Max GCR) available in conventional device link and PCS-based color conversion methods. A simulation method was devised to test the color accuracy, ink usage performance, and printing stability. Results show that the Dynamic K performs as well as ICC-device profiles and Max GCR regarding color accuracy. Additionally, Dynamic K available with Alwan Dynamic DeviceLinks Technology achieves the most amount of ink saving and best printing stability performance.

## 1.0. Introduction

In the current publication and printing industry, the common workflow first converts original files in RGB to the StdPress condition (CMYK) profile, e.g. Web Coated FOGRA 28. In this process, color correction and tone adjustments are made to ensure the CMYK file with the StdPress condition profile can match the RGB file visually and quantitatively. ICC profiles and PCS conversion, being able to achieve a predictable color reproduction, have competence for the “RGB-to-CMYK” conversion purpose.

In the printing stage, the files might be printed on specific presses or printers other than the StdPress condition. To preserve the color accuracy, it is critical to convert the files a second time: from StdPress condition (CMYK1) profile to MyPress condition (CMYK2) profile. With the exception of

traditional PCS conversion, there are various methods to complete this conversion, e.g., DeviceLink Profile and Dynamic DeviceLinks Profile.

DeviceLink Profile has gained much attention since ICC recognized it. Heidelberg composed a user guide to introduce its use of DeviceLink Profile (Heidelberg, n.d.). Device LinkProfile was also introduced in and became an optional feature of X-Rite GretagMacbeth’s ProfileMaker5. DeviceLink Profile attracted attention because it offers a better CMYK-to-CMYK solution than ICC device profiles. Some previous research on DeviceLink Profile testified that it has merits ICC-device profiles cannot compete with (Ploumidis, 2005). For example, DeviceLink Profile offers Maximum Gray Component Replacement (Max GCR) feature; aims to maximize the black component when converting colors from CMYK1 to

CMYK2; and thus realizes reproducing color with less CMY inks without destroying color accuracy.

Another CMYK-to-CMYK technology, Dynamic DeviceLink Profiles (Dynamic DVLP), has been developed by Alwan Color Expertise. One of the highlights of Dynamic DVLP is “Dynamic Maximum Black” (Dynamic K) conversion. According to the manual of AlwanColorHub v3.0, Dynamic K also achieves the use of maximal black replacing CMY combination with intent of saving CMY ink. Different from Max GCR, Dynamic K converts color from CMYK1 to CMYK2 in terms of calculating pixel by pixel. Hence, it claims to be able to optimize CMYK-to-CMYK conversion to a higher level.

While “Dynamic Maximum Black” appears to be attractive, the question is are these merits at the expense of sacrificing the accuracy of color reproduction? How does it perform on saving ink when compared with Max GCR? This research aims to answer these questions by evaluating the effect of Dynamic K of Dynamic DeviceLink Profile in comparison to existing two methods: PCS conversion and Max GCR in DeviceLink Profile.

## 2.0 Objective

This research intends to test three CMYK-to-CMYK conversion methods: (1) ICC-device-profile-based PCS conversion; (2) DeviceLink-Profile-based GCR; and (3) Dynamic DeviceLink Profile-based Dynamic K. The following are the three aspects of performance evaluation: accuracy of color conversion, ink saving; and stability of printing.

## 3.0 Methodology

This section introduces workflows featured by three CMYK-to-CMYK technologies: input and output test targets; StdPress profile and MyPress Profile; and evaluation methodology.

### 3.1 PCRI Images and Profiles

PCRI (Pictorial Color Reference Image) and PCRI chart are used as test targets for both objective and

subjective judgment. PCRI is a collection of 20 digital images with 16 color patches derived from each image. It is designed to bridge the gap between the visual assessment and quantitative analysis (Chung, 2006). This research focuses mostly on data analysis. Figure 1 displays the function of PCRI image and chart.

Two profiles are used in this research: 1) Web

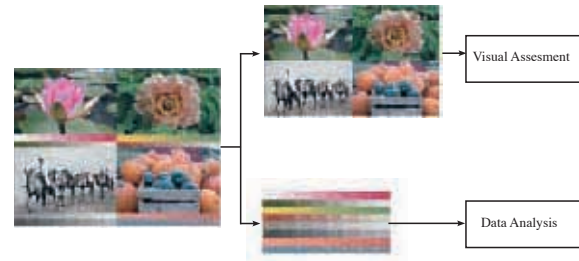


Figure 1. Utilization of PCRI

Coated FOGRA 28 (ISO 12647-2:2004) as StdPress profile; and 2) SM74\_CGATS.icc as MyPress profile. These two profiles are consistently used in three workflows to ensure the workflows are compared in an even condition. For the PCS workflow, color conversion happens in Adobe Photoshop by assigning source device profile and converting to destination profile. Max GCR and Dynamic K are both run in Alwan ColorHub. The software accepts the both StdPress and MyPress profiles and input PCRI files, and then it generates output PCRI files with specific prepress features (Max GCR or Dynamic K).

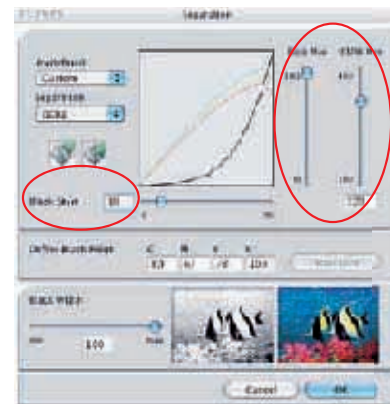


Figure 2. Settings in ProfileMaker to build MyPress profile: SM74\_CGATS.icc

MyPress profile is built with the characteristic data derived from test targets printed by Heidelberg SpeedMaster74 offset. Figure 2 shows the settings in ProfileMaker when building the MyPress profile. Notice that the value of “Black Max” is 100%, “Black start” is 10%, and “CMYK Max” (TAC) is 320%. These parameters indicate that the black starts to replace equivalent CMY combination between tone value from 10% to 100%. These settings are critical and need to be kept consistent throughout all three workflows.

### 3.2 Prepare Input File in StdPress

Convert the PCRI file from original sRGB to CMYK, so that the CMYK file represents the StdPress condition. This process is carried out in Photoshop CS3. The instructions are:

- 1) Launch Photoshop, under the “Edit>Color Setting” option, set the CMYK work space as “Web Coated FOGRA28 (ISO 12647-2:2004)”. 2) Open the PCRI file (TIFF) in Photoshop; select the color management police as “convert document’s colors to the working space”. 3) Save the file as “PCRI\_StdPress.tif” with the current profile (Web Coated FOGRA28 ISO 12647-2:2004) embedded.

### 3.3 Workflows

Figure 3 displays the overall three workflows. “PCRI\_StdPress.tif” acts as the input file that converted to MyPress condition through different workflows. It also serves as the reference, to which output files from three workflows are compared in order to measure the color difference.

#### 3.3.1 PCS Workflow

PCS conversion utilizes Adobe Photoshop CS3 to convert the image to MyPress profile. This workflow uses 1) “PCRI\_StdPress.tif” as input file; 2) “Web Coated FOGRA28. (ISO 12647-2:2004)” as source profile; and 3) “SM74\_CGATS” as destination profile. The output is saved with name of “PCRI\_MyPress\_PCS.tif”. Figure 4 shows the settings for conversion to MyPress in Photoshop. Keep the Black Point Compensation unchecked and select the absolute colorimetric as rendering intent.

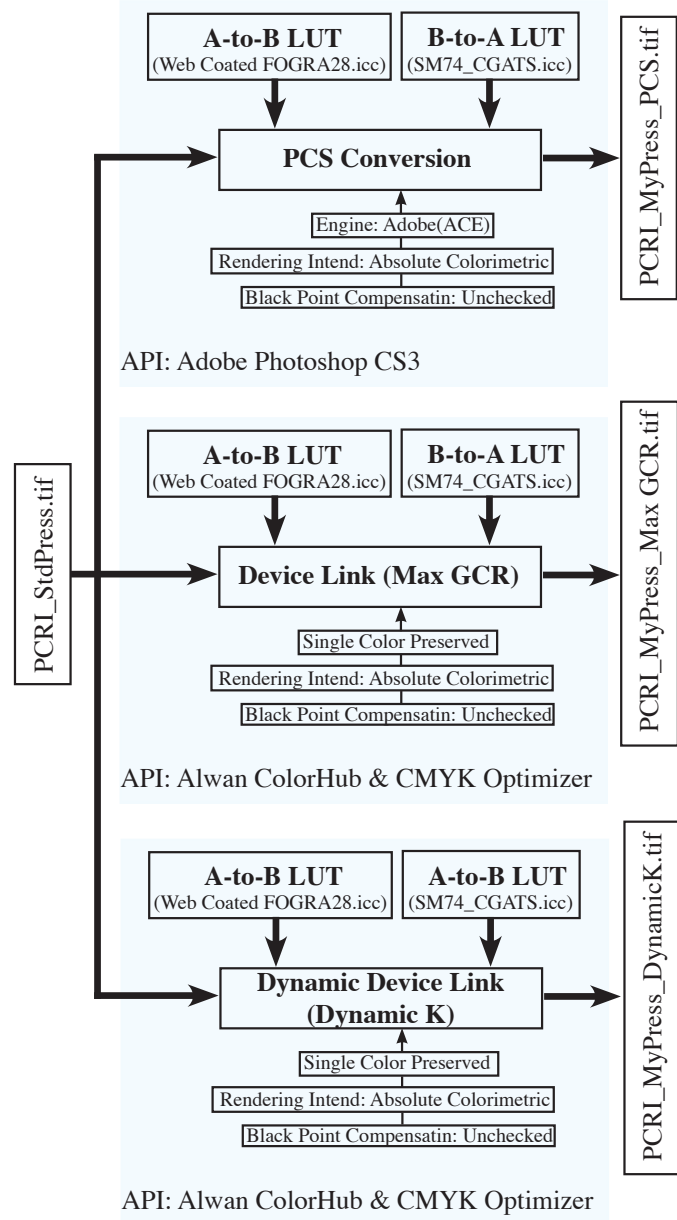


Figure 3. PCS, Max GCR, and Dynamic K workflows



Figure 4. Settings in PhotoShop for PCS workflow

### 3.3.2 Device Link Profile Workflow with Max GCR

This workflow, a feature of Max GCR, transfers color directly between two printing conditions, skipping the PCS. AlwanColorHub is the software used to achieve this conversion using 1) “PCRI\_StdPress.tif” as input file; 2) “Web Coated FOGRA28. (ISO 12647-2:2004)” as source profile; and 3) “SM74\_CGATS” as destination profile.

Figure 5 shows the parameters in AlwanColorHub operation interface. Notice that the “Kmax” value, “TAC”, and “K starts” are the same as those in ProfileMaker when MyPress profile was built (back to Figure 2). The black point compensation choice and rendering intent are exactly the same as the settings in the previous PCS workflow. After all the settings are done, run the workflow and name the output file “PCRI\_MyPress\_MaxGCR.tif.”

### 3.3.3 Dynamic DeviceLink Profile Workflow with Dynamic K

AlwanColorHub with its CMYK Optimizer plug-in is the software used for this process. The parameters are the same as those in the Max GCR workflow, except for the options of optimization settings, which is “Dynamic Maximum Black.” Figure 6 shows the settings for Dynamic K. Notice that “Kmax,” “TAC,” and “K start at” values are kept the same as the other two workflows. Run the process and name the output file “PCRI\_MyPress\_Dynamic K.tif”

### 3.4 Evaluating Color Differences

This section introduces procedures for evaluating color differences between PCRI file in StdPress and MyPress condition. The color difference is evaluated by simulating in CHROMiX ColorThink instead of measuring on hardcopy. Figure 7 shows this concept.

Why use a simulation instead of measuring on hardcopy? Because the workflow itself and its performance are the main research objects, and it is critical to eliminate other disturbing factors caused by inconsistency of printing equipment or measuring

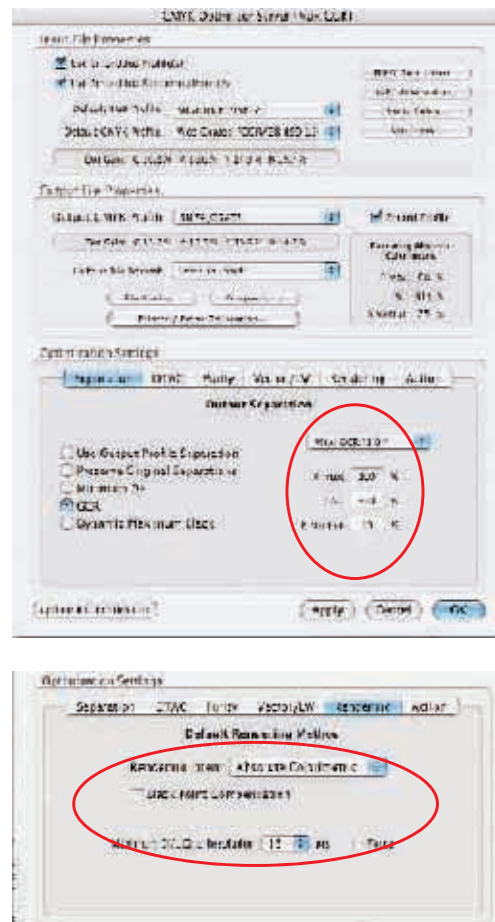


Figure 5. Settings in Alwan ColorHub for GCR workflow

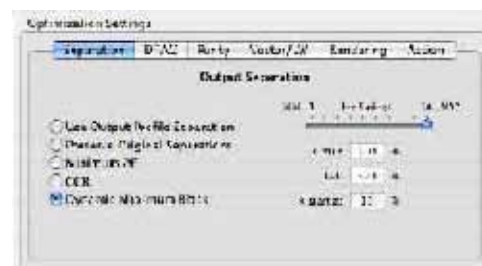


Figure 6. Settings in Dynamic K workflow

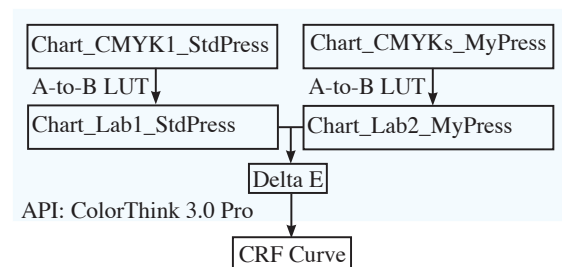


Figure 7. Evaluating color difference by simulating in ColorThink



instrument. Simulation is an effective way to exclude such disturbing factors. In this process, Lab values are derived in terms of simulating in ColorThink.

#### 4.0 Results and Analysis

This section discusses the result of comparing three output files in aspects of color accuracy, ink usage, and resistance to color inconsistency.

##### 4.1 Color Accuracy Evaluation

Three samples coming from three workflows were tested in terms of the color accuracy. Outputs in MyPress are compared with the reference in StdPress to calculate color differences, based on which CRF curves of  $\Delta E 76$  were plotted to compare the performance of three workflows. In Figure 8,  $\Delta E$  values in one specific workflow are sorted from minimum to maximum and ranked along the x-axis. The y-axis indicates the cumulative percentage of a total of 320 color patches. The background is divided into three areas: no visual difference (green), fair color match (yellow), and poor color match (pink) (Chung, 2001).

Except for three curves indicating three workflows, one more curve indicating a no color management situation is added as the contrast. It shows a situation that the file originally in StdPress is printed directly on MyPress device without color management. In Figure 8, “No Color Management” curve locates in “Poor Color Match” area; in the meanwhile, all three “CMYK-to-CMYK” conversion workflows locate in “Fair Color Match” area and overlap together. The conclusion is all three workflows are equally effective in preserving color accuracy when color is produced from one CMYK condition to another.

##### 4.2 Ink Saving Evaluation

The method of evaluating ink saving performance is by: 1) observing the black channel of images; and 2) quantitatively comparing black ink amount and total ink amount using Info panel in PhotoShop. Figure 9 displays the PCRI images after processing by three workflows and the separated black channels. It can be observed that Dynamic K workflow achieves the deepest black when compared with the other two and there is no obvious visual differences among the full CMYK images.

To take a quantitative look at the relationship between black amount and total ink saving, one of the patches shown in Figure 9 is selected and analyzed. Table 1 shows the data of

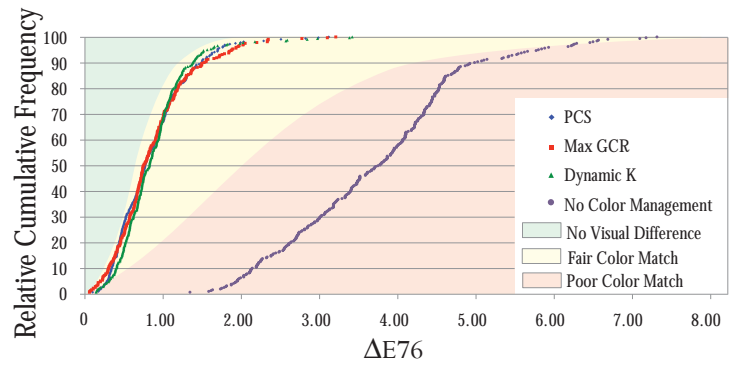


Figure 8. Comparing color differences

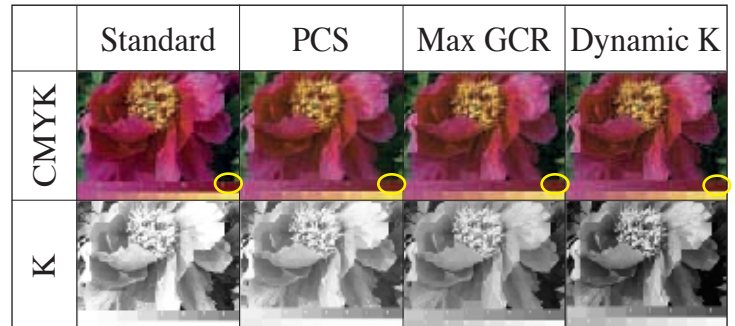


Figure 9. Outputs of three workflows with single black channel

Table 1. Color value of patch sample

	StdPress	MyPress		
	Reference	PCS	Max GCR	Dynamic K
La*b*	L=23;a=38;b=24	L=24;a=36;b=24	L=25;a=35;b=22	L=25;a=34;b=23
CMY	C=21;M=100;Y=87	C=31;M=86;Y=85	C=28;M=84;Y=80	C=0;M=76;Y=60
Black	47	49	53	71
TAC	266%	251%	245%	207%

the selected patch using info panel in Photoshop. Overall, the Lab values of three workflows are quite similar as mentioned earlier in: Color Accuracy Evaluation. Dynamic K generates more K component than either Max GCR or PCS, and the total ink coverage decreases intensively caused by the decreasing CMY replaced by K.

The difference between Max GCR and Dynamic black is the use of Lookup Table (LUT). The Max GCR workflow uses an “A-to-B” LUT to identify the Lab values in StdPress condition. Then based on the Lab values, it finds a proper black component in MyPress condition using a “B-to-A” LUT. In brief, it connects “A-to-B” and “B-to-A” LUT with intent to replace CMY with Black in a certain tone range. The Dynamic K workflow, instead of using “A-to-B” and “B-to-A” LUT, uses two “A-to-B” LUTs, one for StdPress condition and the other for MyPress condition. In doing so, the convention to the destination side is achieved without a predetermined GCR setting.

#### 4.3 Resistance to Device Variations

Device variations are applied by simulating in Photoshop. The simulation assumes that the black component is stable and only the chromatic inks have variation. In this research, outputs of three workflows are adjusted by changing the Magenta tone curve only. Figure 10 shows the curve-adjusting process: the mid-tone and low key is decreased by 5% and 10% to simulate an insufficient Magenta situation. The same adjustment is applied to three files: “PCRI\_MyPress\_PCS.tif,” “PCRI\_MyPress\_Max GCR.tif,” and “PCRI\_MyPress\_Dynamic K.tif.”

The file in StdPress condition acts as the reference, to which three adjusted files are compared. Figure 11 shows the CRF curves that display the color differences between the reference and each of the adjusted file.

Over all, the Dynamic K (green) shows the least color difference. Half of the patches have color differences less than  $4\Delta E$ . In contrast, the PCS (blue)

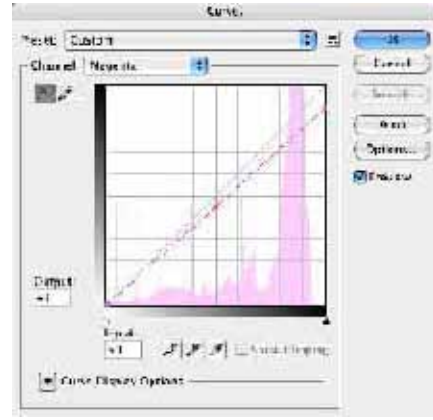


Figure 10 Changing Magenta reproduction curve in PhotoSop

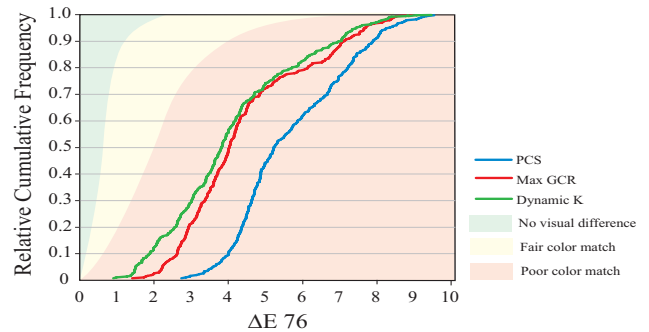


Figure 11 CRF curves indicating color differences between StdPress and MyPress after simulation

performs relatively weak when bearing simulated variation. Only 10% of the color patches were less than  $4\Delta E$ ; the Max GCR performs somewhere between the other two; approximately 40% of the color patches were less than  $4\Delta E$ .

Hence, resistance to (device) variation is another merit of Dynamic K in addition to its ink saving effects. Because “Dynamic K” replaces CMY with K to a large degree, the influence of changing CMY is also alleviated.

#### 5.0 Conclusions

It can be concluded that Dynamic K performs as well as Device Link Profile with Max GCR in terms of color conversion. None of three methods shows noticeable visual differences on a destination device (MyPress). Hence, Dynamic K can be an alternative method for color conversions be-

tween two CMYK devices. Furthermore, Dynamic K featured by Alwan Dynamic DeviceLink Profile behaviors better in maximizing black component in CMYK-to-CMYK color conversions. Replacing CMY with black not only helps save inks and control costs, it also stabilizes the variations in printing process.

## 6.0 Acknowledgements

First of all, I would like to thank Professor Chung for providing me with much insights and encouraging me go ahead with this research. I also want to thank Elie Khoury, Alwan Color Expertise, for donating software to School of Print Media, RIT. I have furthermore to thank Edline Chun. Her editing helped me improve this paper. I would like to express my gratitude all faculty members who were involved in *Test Targets 8.0*; without their support, this book won't be a possible. Finally, I want to say thanks to my parents. Although they are far away in Shanghai, they are the most important people who support me getting throughout my study.

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FYI

### *No More Rich Black*

#### **What is rich black?**

Rich black is an ink mixture of solid black over one or more of the other (CMY) colors. Rich blacks are used to increase the density of a black area. However, rich black lines or text in a graph or table are problematic. When viewed on a monitor they seem OK, but when printed, text seems to be bold and registration for offset printing becomes very critical. An effective way to detect the rich black problem is to make a PDF file and open it in Adobe Acrobat. Acrobat provides a feature called “Output Preview,” which lists all colors used in that file. When K ink is unchecked and the black lines do not disappear, this means that the lines are rich black.

#### **How do we get rich black?**

The problem occurs mostly with graphs and tables made with Microsoft Excel. Colors in Excel are defined in RGB color space, and when converted to CMYK, rich blacks result.

#### **How is rich black removed?**

Import tables or charts into Adobe Illustrator, using CMYK color space. Select a “black” line and observe the values of the color components in the color window. If CMY is not zero, then go to Select > Same > Fill & Stroke, which selects all other lines with that same color, and then set the CMY components to zero. This also applies to gray lines and text. After resetting the color values, save the file as either EPS or PDF and recheck for rich blacks in Acrobat.

(submitted by Jiayi Zhou)



# Color Gamut Quantified

## A New Approach to Analyzing Color Gamut

*Bill Pope, Fred Hsu, and Franz Sigg*  
*bpope@flexography.org; cyhter@rit.edu; fxsppr@rit.edu*

### Keywords

Color gamut, Color management

### Abstract

High impact color continues to be a goal of publishers, consumer products companies, and all who use print to communicate their message in an attempt to gain market share and increase sales. As a result, all those involved in the value chain, such as designers, suppliers, and printers, aim to contribute positively towards this goal. As efforts have been made to increase the colorfulness of print, it has been difficult to quantify the size of the color gamut.

Recently, there have been developments by various color management software vendors to provide tools that quantify the size of the color gamut by evaluating ICC profiles. This paper introduces a new color gamut analysis tool developed at Rochester Institute of Technology along with an overview of the other commercially available applications. Using these approaches, case studies will be presented showing gamut differences between various combinations of printing technologies and consumables.

### 1.0 Introduction

The impact of color on the human visual response system is well understood in all facets of visual communications ranging from television to the various forms of print. At one point each of these was monochromatic, or just “black and white.” Computer monitors have gone from various single-color versions (green, amber, gray, etc.) acting strictly as terminals for interacting with a computer to now high-definition color-managed displays that enable remote soft-proofing and are replacing hard-copy proofing systems.

In packaging, fast moving consumer products companies (CPCs) believe the link between the shelf appeal of the package and sales is very direct and very strong. Gains in market share have been directly tied to enhancements in graphics, design, the use of various visual enhancement features (i.e., holographic films, etc.), and color. To enhance the colorfulness of the printed product, or enlarge the gamut of reproducible colors, colorants (inks) have been focused on as a chief component.

To expand the gamut, multiple approaches have been developed. One approach has simply been to print the process inks (cyan, magenta, yellow, and black) to higher solid ink densities (SID). While this approach does enlarge the gamut to an extent, there are often trade-offs. First, if printed to too high of a density, a color can actually lose chromaticity and result in a smaller gamut. There can also be issues associated with thicker ink film thicknesses, such as drying or curing problems, problems with stability on a printing press, higher cost for the printed product, and others.

Another approach has been to use colorants beyond CMYK. This approach is often referred to as “extended gamut printing.” Here, complementary colors are used to reproduce colors that cyan, magenta, and yellow cannot in combination. One system known as Hexachrome (Reid & Apostol, 2004) utilizes orange and green to accomplish this while another named Opaltone (Opalton, n.d.) utilizes red, green, and blue. In addition to extending the gamut for purposes of colorfulness, both

systems aim at helping to reproduce spot colors, or PMS (Pantone Matching System) colors. This becomes valuable when printers are faced with many individual colors in a job. Instead of printing each color in its own station, the extended gamut approach allows printers to use the six or seven colors in some sort of combination to reproduce the specified colors to minimize the number of required print stations and subsequent manufacturing costs.

Whatever the approach, understanding the impact on the color gamut is important if one wants to characterize and improve it. Even for traditional, non-gamut expanding approaches, it is valuable to understand the color gamut for process control and continuous improvement. Many factors impact the color gamut, such as: inks/colorants, substrate, other process consumables, color sequence, the type of printing process itself, and others.

## 2.0 Legacy Approach

Traditionally, describing and characterizing color gamuts have been done one of two ways. Both are based on CIE (Commission Internationale de l'Eclairage) colorimetry. While this is not the place for a thorough review of color theory and color spaces, it should be understood that describing color is three-dimensional with the three ordinates

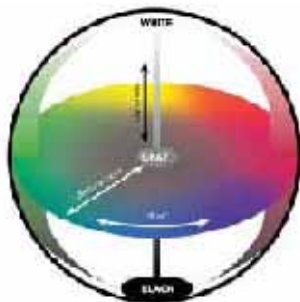


Figure 1. A typical color space. (Image courtesy of X-Rite)

being lightness, chromaticity (or saturation), and hue (Figure 1).

One plotting technique utilizes the CIE Chromaticity Diagram (see Figure 2). Here, color is plotted in terms of hue and chromaticity in two dimensions. Lightness is not accounted for in this approach. Color gamuts can be portrayed by plot-

ting multiple points to create an irregular closed shape. This represents the boundary of the particular imaging system in terms of its color gamut and achievable colors. Colors that fall outside the plot are not reproducible by the system while colors that fall inside the plot can be reproduced.

Figure 2 shows the gamut boundary of an ink-jet printer (the larger plot) along with a gamut boundary of a typical web offset printing press. On one hand, it does show a significant difference between the two devices. However, since color is three-dimensional and this plotting technique only plots in two dimensions (lightness is missing), it is not possible to ascertain which specific colors fall inside or outside the gamut. Other shortcomings include the fact that equal distances on the diagram do not correspond to equal visual differences; the diagram was originally designed to plot the color of light sources as opposed to the color of objects. And lastly, there is no way to quantify the gamut.

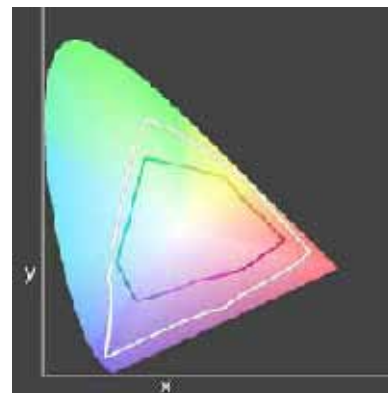


Figure 2. x-y color space

A second approach involves plotting color in the CIELAB color space (Figure 3). Here, colors can be described numerically in three dimensions with  $L^*$  representing lightness, and  $a^*$  and  $b^*$  used to locate a color in the color space so that hue and chromaticity can be calculated and assessed.  $L^*$  serves as the vertical axis while  $a^*$  and  $b^*$  serve as the x-y axes. Often,  $L^*$  is plotted separately from  $a^*$  and  $b^*$ , which are plotted two-dimensionally. Further,  $C^*$  (chroma) and  $h_o$  (hue angle) are calculations based on  $a^*$  and  $b^*$  to derive colorimetric values for chromaticity and hue. To display the gamut, a hexagonal plot is made utilizing the three

subtractive primary colorants (cyan, magenta, and yellow) along with the overprints of the three (red, green, and blue).

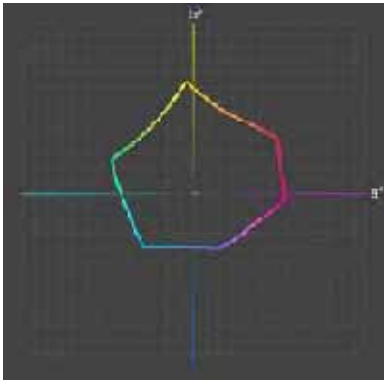


Figure 3.  $a^*b^*$  plot

This approach also suffers from the fact that it is only two-dimensional. However, with the  $L^*a^*b^*$  coordinates known, calculations can be made of the area of the hexagonal plot and used to compare various conditions, to some level. This approach does not discriminate where the six endpoints fall along the lightness axis. Hence, it is not a valuable calculation. These color space systems are used conceptually to explain terms of normal color descriptors (Field, 1999).

### 3.0 Newer Approaches

With the advent of color management and ICC profiles, a large sampling of a device's color output can be used to mathematically describe the three-dimensional nature of the device's color output. The steps include:

1. Output of a profiling target (CMYK for hard-copy, RGB for monitors).
2. Color measurement of the target utilizing spectrophotometry. The result is a data set of  $L^*a^*b^*$  values for each patch in the profiling target.
3. Generation of the ICC profile.

The profile represents how that device renders color given a particular input (CMYK or RGB values). Once it has been created, the profile is primarily used to convert image data either from one color space to another (RGB to CMYK or CMYK to RGB) or within a color space (CMYK

to CMYK or RGB to RGB). This is how various devices simulate the color output of other devices. For example, computer displays can act as "soft proofing" devices simulating the color output of a printing press.

Another application is to color manage a digital hard-copy proof to a printing press. Using ICC color management allows for color to be managed from image capture, or acquisition (digital camera/scanner), to proofing (soft or hard copy) to final output (printed or displayed).

Profiles also serve in graphically displaying the three-dimensional nature of a device's color gamut as well as enable calculations of the volume of the gamut. Various vendors of color management software (Figure 4 and Figure 5) have this capability. Figure 4 is a screen shot of the same inkjet and web offset profiles that were plotted in the chromaticity diagram. Note how the three-dimensional plot offers much more clarity and insight about the shape and volume of the two device's gamuts. The software also allows users to rotate and spin

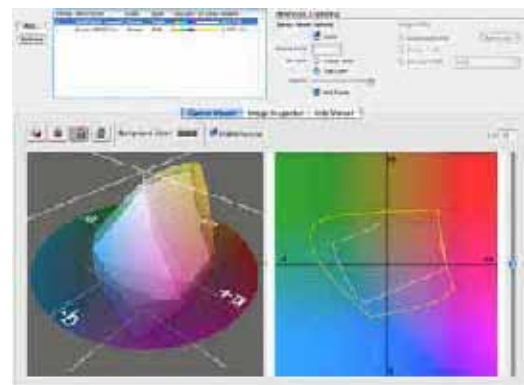


Figure 4. X-Rite Monaco Gamut Works

the three-dimensional plots so that the gamuts can be viewed from any desired perspective. Additionally, calculations of the gamut's volume are available within the software. However, typically just one number representing the gamut volume is generated as seen in Figure 5. Other than a visual assessment of the plots, there is no way to ascertain where differences in gamuts between devices exist.

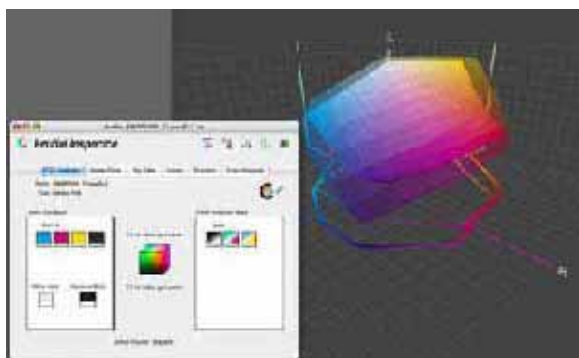


Figure 5. CHROMiX ColorThink Pro 3.0

#### 4.0 The RIT Gamut Analysis Tool

Identifying a need to understand better where differences can lie in gamuts, Rochester Institute of Technology has developed a tool that utilizes ICC profiles to plot features of gamuts of interest in a unique way. The primary plotting technique uses  $L^*/C^*$  slices at eight (8) different hue angles, 45-degrees apart, around the entire  $a^*b^*$  plane. Each analysis generates a two-page report (see Appendix) containing the various plots along with tabular data about gamut size for each hue angle and totaled for overall gamut volume.

In the RIT Gamut Analysis Report, the figure on page 31 shows  $L^*/C^*$  plots of the eight hue angles for the inkjet and web offset printing example. Each of the eight plots shows the following:

- Plots of both conditions of interest
- A plot of a reference condition taken from the ISO 12640-3.4 Draft which represents “real world” colors of very high chroma including natural colors – not necessarily printed.
- Color-coding of the plots corresponding to the hue angle
- A legend for each condition with calculated areas for the  $L^*/C^*$  slice

To arrive at a quantitative volume of the gamut, each of the eight calculated areas is added together. The resulting value can then be compared to other conditions.

The second page of the report shows a two-dimensional plot of the gamuts in the  $a^*b^*$  plane along

with tabular  $L^*a^*b^*$  data for the substrate, the individual CMYK colorants, the overprint colors (RGB) and a 400% patch of CMYK. Additionally, gamut areas for the eight  $L^*C^*$  slices are summarized for the reference and sample conditions along with percentage calculations of the differences of the sample versus the reference and the sample versus the real world condition. Finally, the eight area calculations are summed for a total gamut volume.

This analysis technique is very flexible in that it can be used to compare any two conditions, be it different printing processes and/or imaging systems, different ink/colorant systems, different substrates, etc. In the appendix are examples of three analyses illustrating different types of comparisons.

#### 5.0 Summary

With color becoming more and more important in the eyes of purchasers of various forms of printing, be it newspapers, magazines, packaging, or any other printed material, understanding the influence of various consumables with the various printing processes on the final color is vital. Having the ability to quantify the size of the color gamut along with understanding how gamuts are different between various conditions will help all those in the value chain to continuously improve and enhance the colorfulness of print.

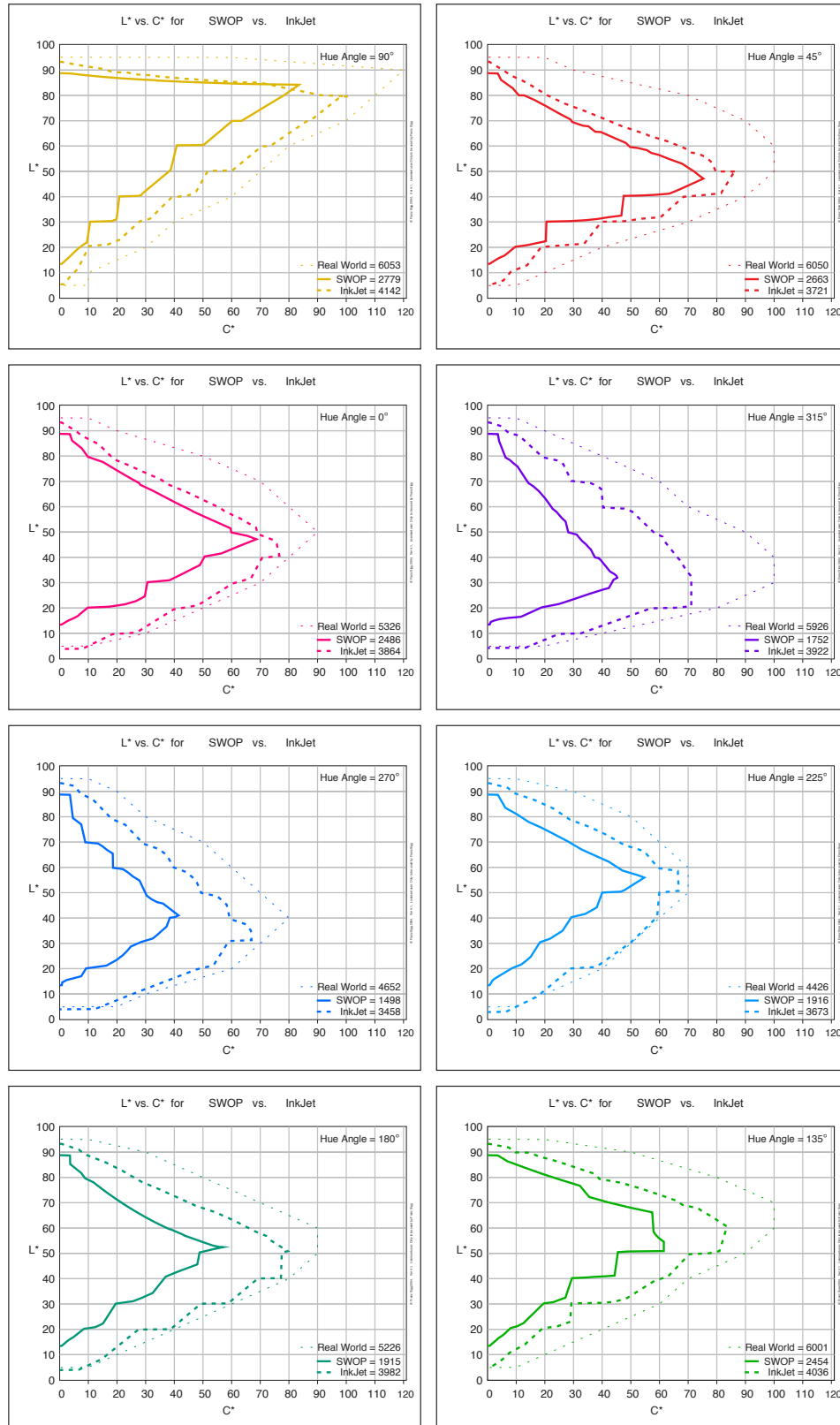
#### 6.0 References

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- Opalitone (n.d.) *What is Opalitone?* from Opalitone website:  
<http://opalitone.com/What-is-Opalitone-158.cms>.
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# Appendix. RIT Gamut Analysis Report

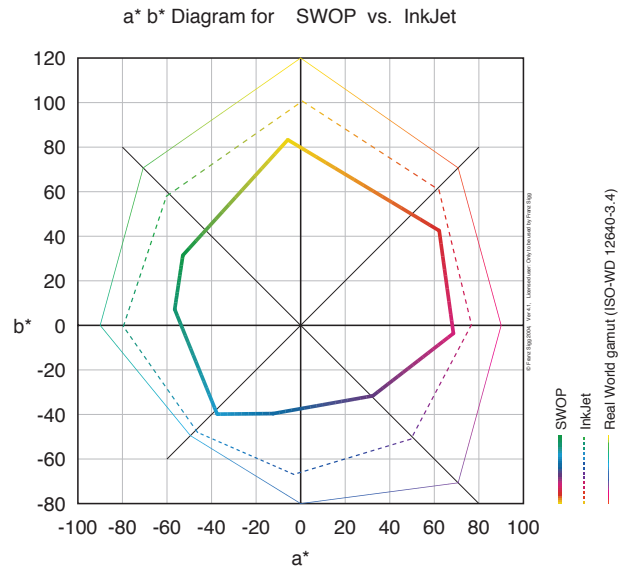
## Gamut Quantification, SWOP vs. InkJet

Note: It is well known that a step difference in yellow is visually less significant than a step difference in blue.  
Gamut comparisons in CIE Lab should therefore be limited to comparing same hue angles only. CIE Lab is not visually equidistant.





## RIT Gamut Analysis Report-page 2



### CIELab for special patches

Patch	L*	a*	b*
Paper	88.73	-0.25	3.64
400% solid	9.08	0.54	1.2
K solid	18.62	0.89	1.26
C solid	55.87	-37.53	-40.26
C+Y solid	51.61	-61.11	26.35
Y solid	84.29	-5.93	83.42
M+Y solid	46.84	62.85	42.18
M solid	47.16	68.56	-3.61
C+M solid	26.35	17.96	-41.32

### SWOP

### Gamut areas for the 8 L\*C\* slices:

Color	Hue_Angle	SWOP Sample	InkJet Reference	Samp / Ref	Samp / Real World
Yellow	90	2779	4142	67 %	46%
Red	45	2663	3721	72 %	44%
Magenta	0	2486	3864	64 %	47%
Purple	315	1752	3922	45 %	30%
Blue	270	1498	3458	43 %	32%
Cyan	225	1916	3673	52 %	43%
Emerald	180	1915	3982	48 %	37%
Green	135	2454	4036	61 %	41%
Total		17463	30798	57 %	40%

Note: It is well known that a step difference in yellow is visually less significant than a step difference in blue.

Gamut comparisons in CIELab should therefore be limited to comparing same hue angles only.

CIELab is not visually equidistant. The totals numbers are therefore to be used with great caution.

Real World colors are all the colors that might have to be reproduced as specified by ISO 12640-3.4 draft.



# A Study of Ink Trapping and Ink Trapping Ratio

Robert Chung and Fred Hsu  
*rycprr@rit.edu; cyhter@rit.edu*

## Keywords

ink trapping, ink trapping ratio, process color, spot color

## Abstract

Ink trapping is defined as the amount of the second ink transferred on top of the first ink during process color printing. It is estimated optically with the use of densities. This research devised a method whereby the weight of an inked cylinder before and after ink transfer on to an already inked surface is recorded. The ratio is then calculated between the weight loss in wet-on-wet ink transfer and the weight loss in wet-on-dry ink transfer. We define the ratio as the weight-based ink trapping ratio (ITR). The density-based ITR is defined as the ratio of the 'wet-on-wet' ink trapping and the 'wet-on-dry' ink trapping. Weight-based and density-based ink trapping ratios are compared. The effect of ink sequence and ink trapping ratio on overprint colors are examined.

## 1.0 Introduction

Printing is about transferring ink from an image carrier to substrate. At the printing nip, the ink splits. A portion of the ink transfers to the substrate while the rest remains on the image carrier. Walker & Fetsko (1955) published the first paper on ink transfer mechanism based on printing oil-based black inks on coated paper using a letter-press.

In multi-color lithographic printing, ink transfer from the first printing unit on to substrate is wet-on-dry. Subsequent printing units print wet-on-wet on already printed area. Concerning the ability of the second ink transferring on top of the first

printed ink, Frank Preucil (1953) developed the first density-based ink trapping formula as shown in Figure 1.

Here, D1 is the solid tone density of the first-down ink; D2 is the solid tone density of the second-down ink; and D3 is the density of the overprint solid. In addition, dry densities are measured via complementary filter of the second-down ink. As shown in Figure 1, the first-down ink is cyan and the second-down ink is magenta. The green filter density of cyan solid (D1), magenta solid (D2), and C+M overprint (D3), after subtracting the paper density, are entered into the formula for ink trapping calculation.

Ink trapping has been considered to be an important process control parameter. This is because important memory colors, e.g., red of the apple, green of the grass, and blue of the sky, in pictorial color image reproduction are all two-color overprints. Ink trapping, thus, helps quantify how two process colors interact during printing, i.e., when the ink trapping value changes, the hue of the overprint is likely to change.

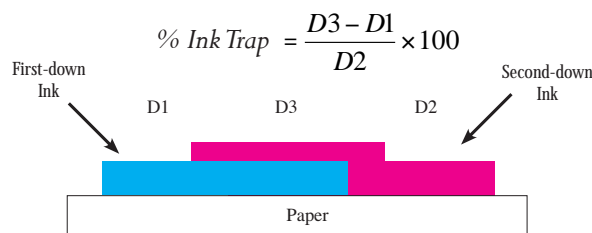


Figure 1. Density-based ink trapping formula

Traditionally, ink trapping only applies to two-color overprint. Ink trapping between the black and chromatic process inks is not mentioned, nor is the ink trapping in spot-color printing.

*ISO 12647:2004 Graphic technology — Process control for the production of half-tone colour separations, proof and production prints — Part 1: Parameters and measurement methods* defines printing process control parameters. Today, it downplays the importance of ink trapping. Instead of specifying ink trapping, it opts for specifying colorimetric values of two-color overprints, i.e., (Y+M) red, (Y+C) green, and (M+C) blue, directly.

## 2.0 Research Objectives

Recent research shows that a spectral-based ink trapping model can be used to predict spot color overprint (Viggiano & Prakhya, 2008). Input data include spectral reflectance of two solids and the substrate. The problem is that there are two unknowns, ink trapping factor and the overprint color, in one equation. Recognizing the dilemma, this research sets out to devise a method whereby ink trapping factor is estimated independently, hence, the weight-based ink trapping assessment.

The research question is, “Do weight-based ink trapping and density-based ink trapping correlate with each other?” If ink trapping can be determined from ink weight as opposed to the color of the inks and their overprint, there may be a solution in predicting overprint colors of any two inks.

## 3.0 Methodology

In terms of sample preparation, there are three stages to consider: (1) producing single ink samples, (2) producing wet-on-dry overprint samples, and (3) producing wet-on-wet overprint samples. To start, we will study ink trapping using process color inks.

### 3.1 Single-ink Sample Generation

The first step is to determine how single-ink samples with known density or color are prepared. A step-by-step procedure is shown below:

1. Deposit known amount of ink to the IGT High Speed Inker Unit 4 using a pipette (Figure 2).
2. Mount a removable cylinder to the Inker.
3. Transfer the ink from the Inker to the cylinder.
4. Mount the inked cylinder to the IGT Printability Tester AIC2-5.



Figure 2. IGT High Speed Inker

5. Transfer the ink from the inked cylinder to a paper specimen in the IGT printability tester (Figure 3).
6. Allow ink sample to dry at least six hours.
7. Measure density and color of the sample. Three measurements are collected from a sample.



Figure 3. IGT Printability tester

8. Determine the amount of ink needed to match target densities for process inks or target colorimetric values of spot color inks.

To be specific, the net weight of the cylinder is 150.325 g. The initial ink amount, e.g., 0.10 cc, is applied from the pipette to the IGT High Speed Inker. The difference between the inked cylinder weight and the net cylinder weight is 0.023g. Table 1 shows the amount of inks needed from the pipette to produce a given density for magenta, yellow, and black ink.

*Table 1. Ink amount and density relationship of single-ink samples*

Ink	Amount (cc)	Density
Magenta	0.08	1.42
Yellow	0.10	1.04
Black	0.10	1.73

### 3.2 Wet-on-dry Overprint Sample Generation

The above single-ink sample generation procedure (Steps 1 through 6) is appended below to produce wet-on-dry overprint samples and to measure the amount of second ink loss. Two samples are generated per ink sequence.

3a. Measure the weight of the inked cylinder with a precision scale with a tolerance of 0.0005 g (Figure 4).



*Figure 4. Precision scale*

5. Transfer the ink from the inked cylinder to a piece of paper, already printed with the first ink, using a printability tester.

5a. Measure the weight of the inked cylinder afterward.

6. Determine the weight loss between 5a and 3a. We'll denote the difference in gram as  $\Delta W$  (wet-on-dry).

### 3.3 Wet-on-wet Overprint Sample Generation

Wet-on-wet overprint samples are prepared by mounting two removable cylinders on the IGT Printability Tester so that the second ink is transferred on top of the first ink in a single pass. Only the weight loss of the second ink is measured. We'll denote the weight difference in gram as  $\Delta W$  (wet-on-wet).

### 3.4 Weight-based Ink Trapping Ratio

In this research, ink trapping ratio (ITR) is operationally defined as the proportion of weight loss of the second ink at wet-on-wet overprinting with respect to the weight loss at wet-on-dry overprint or

$$\% ITR_{\text{weight-based}} = \frac{\Delta W_{\text{wet-on-wet}}}{\Delta W_{\text{wet-on-dry}}} \times 100$$

The weight-based ITR formula is different from the density-based ink trapping formula. First, the weight-based ITR formula stems from physical quantities of weight loss between two ink transfer conditions using bench-top equipment; the density-based ink trapping formula is based one, on (wet-on-wet) ink transfer condition during printing. Second, the weight-based ITR formula is a ratio of weight loss between wet and dry ink transfer and does not depend on the colorimetric properties of the inks; the density-based ink trapping depends on the light absorption of the second ink and assumes that densities are additive.

In this research, we want to answer the following three questions: "How do density-based ink trapping and weight-based ITR compare with each other?" "What is the ink trapping difference in printing black first and last in process color printing?" In addition, "What is the effect of two spot-color ink sequences on resulting overprint colors?"

## 4.0 Results

Results are explained by comparing density-based ink trapping and weight-based ITR, effect of ink sequence on its overprint colors, and effect of ink sequence on spot-color overprint.

### 4.1 Comparing Density-based Ink Trapping and Weight-based ITR

By measuring the ‘yellow over magenta’ overprint samples under the wet-on-dry ink transfer conditions, the density-based ink trapping values are shown in Table 2. Notice that yellow is the second-down ink, thus, the blue filter densities (as highlighted in blue) are used in the ink trapping calculation.

By measuring the ‘yellow over magenta’ overprint samples under the wet-on-wet ink transfer conditions, the density-based ink trapping values are shown in Table 3. Two observations are worthy of mention: (1) the wet-on-dry ink trapping (91.1%) is less than 100% because reflection densities are not additive; and (2) the wet-on-wet ink trapping value (74.2%) is, as expected, less than the wet-on-dry ink trapping (91.1%).

By using the weight loss data in the preparation of the ‘yellow over magenta’ overprint samples, the

weight-based ITR calculation is shown in Table 4. Notice that the net ink weight on the cylinder is 0.023g and the weight loss due to ink transfer to paper is 0.012 g or one-half of the initial amounts of ink.

By observation, the weight-based ITR value of 80% is between the two density-based ink trapping values. If we take the ratio of the wet-on-wet density-based ink trapping value and the wet-on-dry density-based ink trapping value, i.e., 74.2 divided by 91.1, the density-based ITR or 79% is very close to the weight-based ITR value (80%).

$$\%ITR_{density-based} = \frac{InkTrap_{wet-on-wet}}{InkTrap_{wet-on-dry}} \times 100$$

If weight-based ITR and density-based ITR are linear to each other, we can assess the weight-based ITR independently of any press run and use it as an ink trapping factor to predict the colorimetric value of two-color overprint in a press run.

Table 4. Weight-based ITR for yellow over magenta

Y over M	Weight (g)	Wet-on-dry	Wet-on-wet
Test #1	Before print	150.348	150.352
	After print	150.336	150.341
	$\Delta W$	0.012	0.011
Test #2	Before print	150.351	150.353
	After Print	150.338	150.344
	$\Delta W$	0.013	0.009
Ave. $\Delta W$ (wet-on-dry)		0.0125	0.0100
Weight-based ITR		80%	

Table 2. Density-based ink trapping (wet-on-dry)

Y over M	Wet-on-dry	Dv	Dr	Dg	Db	D-based trap
	Paper	0.06	0.06	0.05	0.03	
Test #1	M (D1)	0.65	0.26	1.49	0.79	89.2%
	Y (D2)	0.10	0.08	0.12	1.04	
	Y on M (D3)	0.64	0.25	1.50	1.69	
Test #2	M (D1)	0.65	0.26	1.49	0.79	93.0%
	Y (D2)	0.10	0.08	0.12	1.04	
	Y on M (D3)	0.66	0.26	1.57	1.73	
Ave. (wet-on-dry)						91.1%

Table 3. Density-based ink trapping (wet-on-wet)

Y over M	Wet-on-wet	Dv	Dr	Dg	Db	D-based trap
	Paper	0.06	0.06	0.05	0.03	
Test #1	M (D1)	0.65	0.26	1.49	0.79	76.0%
	Y (D2)	0.10	0.08	0.12	1.04	
	Y on M (D3)	0.64	0.25	1.47	1.56	
Test #2	M (D1)	0.65	0.26	1.49	0.79	72.4%
	Y (D2)	0.10	0.08	0.12	1.04	
	Y on M (D3)	0.63	0.24	1.42	1.52	
Ave. (wet-on-wet)						74.2%

## 4.2 Effect of Ink Sequence on its Overprint Colors

We studied black and yellow ink sequences and how they impact their overprint colors. Table 5 compares the weight-based ITR between the two ink sequences of 'yellow-over-black' and 'black-over-yellow.' In this case, the weight-based ITR of yellow-over-black is 88%, which is higher than that of the black-over-yellow ITR (19%).

By means of visual and colorimetric examination, the yellow-over-black 'wet-on-dry' overprint appears darker (9.8 L\*) than the black-over-yellow 'wet-on-dry' overprint (14.8 L\*). A major cause of the trapping difference is ink tack. In this case, the black ink tack (17.4) is higher than the yellow ink tack (12.2) that hinders the wet black ink transfer to the wet yellow ink. Consequently, less black is transferred on top of the yellow ink and the resulting overprint is less dark.

Table 6 shows the density-based ink trapping of yellow-over-black overprint. The result shows that both trapping values, wet-over-dry (36.7%) and wet-over-wet (34.3%), are quite smaller than the weight-based value (88%). However, the density-based ITR (93.5%) is closer to the weight-based value.

Table 7 shows the density-based ink trapping of black-over-yellow overprint. While the 'wet-on-dry' ink trapping (95.4%) is high, the black ink tack is believed to be the culprit for low 'wet-on-wet' ink trapping (11.1%). Again, the density-based ITR or 11.6% is close to the weight-based ITR of 19%.

To apply the ITR calculations to spot-color inks, we examined the interaction between Pantone 1788 (red) and Pantone 7466 (turquoise) in two ink sequences. Table 8 shows the weight-based ITR

Table 5. Weight-based ITR of black and yellow in two sequences

Ink sequence		Y over K		K over Y	
	Weight (g)	Wet-on-dry	Wet-on-wet	Wet-on-dry	Wet-on-wet
Test #1	Before print	150.332	150.335	150.331	150.331
	After print	150.32	150.323	150.32	150.329
	$\Delta W$	0.012	0.012	0.011	0.002
Test #2	Before print	150.334	150.333	150.331	150.331
	After print	150.32	150.322	150.321	150.329
	Weight loss	0.014	0.011	0.01	0.002
	Ave. $\Delta W$	0.013	0.0115	0.0105	0.0020
Weight-based ITR		88%		19%	

Table 6. Density-based ink trapping for yellow over black

Y over K		Db	Wet-on-dry	Db	Wet-on-wet
	Paper	0.03		0.03	
Test #1	K (D1)	1.76		1.76	
	Y (D2)	1.09	36.1%	1.09	35.2%
	Y on K (D3)	2.14		2.02	
Test #2	K (D1)	1.76		1.76	
	Y (D2)	1.09	37.2%	1.09	33.4%
	Y on K (D3)	2.15		2.00	
Ave.			36.7%		34.3%

Table 7. Density-based ink trapping for black over yellow

K over Y		Dv	Wet-on-dry	Dv	Wet-on-wet
	Paper	0.056		0.056	
Test #1	Y (D1)	0.10		0.10	
	K (D2)	1.76	95.1%	1.76	9.7%
	K on Y (D3)	1.72		0.26	
Test #2	Y (D1)	0.10		0.10	
	K (D2)	1.76	95.7%	1.76	12.5%
	K on Y (D3)	1.73		0.31	
Ave.			95.4%		11.1%



of Pantone 1788 over 7466 to be 41%. Table 9 shows the weight-based ITR of Pantone 7466 over 1788 to be 63%.

Table 8. Weight-based ITR for two spot colors  
(1788 on 7466)

1788 on 7466	Weight (g)	Wet-on-dry	Wet-on-wet
Test #1	Before print	150.366	150.328
	After print	150.351	150.322
	$\Delta W$	0.015	0.006
Test #2	Before print	150.381	150.329
	After print	150.364	150.322
	Weight loss	0.017	0.007
Ave. $\Delta W$		0.016	0.0065
Weight-based ITR		41%	

Table 9. Weight-based ITR for two spot colors  
(7466 on 1788)

7466 on 1788	Weight (g)	Wet-on-dry	Wet-on-wet
Test #2	Before print	150.355	150.345
	After print	150.338	150.334
	$\Delta W$	0.017	0.011
Test #2	Before print	150.364	150.344
	After print	150.346	150.333
	Weight loss	0.018	0.011
Ave. $\Delta W$		0.0175	0.0110
Weight-based ITR		63%	

By examining all ink samples of ‘wet-on-dry’ and ‘wet-on-wet’ ink transfer, there is a straight-line relationship between density-based ITR and weight-based ITR over a wide range of ITR values (Figure 5).

This finding suggests that the weight-based ITR, derived from lab testing, correlates with density-based ITR, derived from a press run. Imagine for a moment if we print with uni-tack inks, i.e., inks

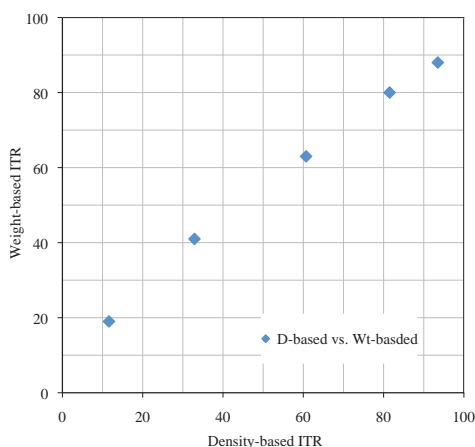


Figure 5. Correlation between density-based ITR and weight-based ITR

having the same tack, the weight-based ink trapping behavior should be similar regardless of the color of the ink. Therefore, we can treat ink trapping factor as a constant when predicting any two overprint colors in premedia simulation.

#### 4.3 Effect of Ink Sequence on Spot Color Overprint

Figure 6 shows the colorimetric ( $a^*b^*$ ) properties of the two spot-color inks and their overprint solids in two ink sequences. Here,  $a^*b^*$  values of the Pantone 1788C (red; upper right) and Pantone 7466C (turquoise; lower left) are plotted in the opposite corners of the graph. The spot-color overprint of 1788 over 7466 is closer to the first ink (turquoise). Likewise, the spot-color overprint of 7466 over 1788 is reddish.

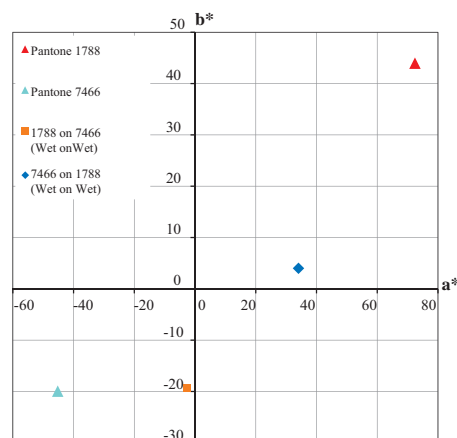


Figure 6. Colorimetric plots of spot color solids and their overprints

Ordinarily, we think of the second ink being more influential in the appearance of the overprint than the first ink. The outcome of the experiment is counter-intuitive in that the second-down ink has less influence on the hue of its overprint than the first ink. In addition, the color difference between the two overprints, due to ink sequence differences, is large (46  $\Delta E_{ab}$ ) and very visible.

The experimental finding is consistent with the offset sheet-fed press experiment reported earlier (Chung, Riordan & Prakhya, 2008). There are many spot colors available in the custom color



libraries. While ‘overprint fill’ is a design feature, there is no mechanism to simulate the overprint colors accurately in premedia software. In other words, premedia software needs to do a better job in simulating spot-color overprints by taking ink sequence and ink trapping into considerations.

## 5.0 Conclusions

There is a significant difference between ‘wet-on-dry’ and ‘wet-on-wet’ density-base ink trapping values. The ink tack affects wet-on-wet ink trapping. In other words, the color of the overprint changes as a function of ink sequence. In this study, when ink sequences are altered between black ink (high tack) and yellow ink (low tack), the ‘black over yellow’ overprint results in less darkness than the ‘yellow over black’ overprint.

Spot colors used to be printed in isolation to one another in packaging printing. Today, spot-color overprints are enabled by premedia software that adds visual appeal to packaging graphics. This research points out that spot-color overprint is very much a function of the ink sequence. The prediction of the overprint color depends on ink trapping and ink transparency of spot-color inks involved.

A weight-based ink trapping ratio assessment was devised using bench-top ink testing equipment. There is good correlation between weight-based ink trapping ratio and density-based ink trapping ratio. If the tack of all spot-color inks is the same, then weight-based ITR will be independent of the color of the ink. It provides a starting point to predict overprint colors of any two inks in premedia simulation. In addition, a follow-up study is to use the black ink exclusively as the first-down ink when preparing wet-to-dry ink samples. In doing so, ink transparency can also be added to the prediction of overprint colors.

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### *Imposition and Finishing Processes*

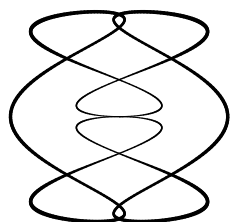
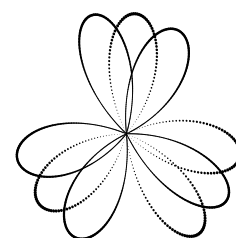
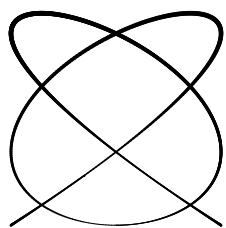
This edition of *Test Targets* was printed using both the HP Indigo 5500 and the RIT sheet-fed press, respectfully known as the Heidelberg Speedmaster 74. The limitation of page sizes resulted in the Hewlett-Packard 5500 producing 4-page signatures (2/2), while the SM74 produced 8-page signatures (4/4).

The final book was finished using a method called Smyth Sewn binding. This binding procedure is a combination of stitching the signatures together, followed by a liberal application of glue to attach the cover. As a result this particular binding creates a durable spine intended to hold up through years of use.

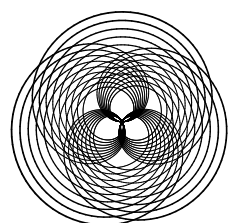
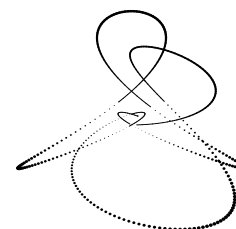
(submitted by Stephanie Pieruccini)

# GALLERY OF VISUAL INTEREST

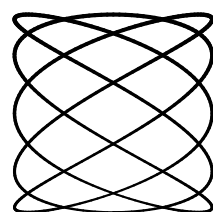
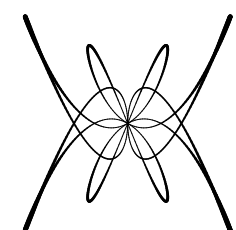




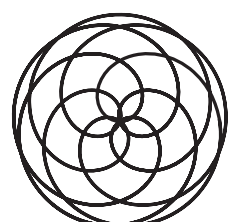
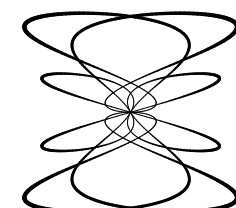
Franz Sigg  
fxsppr@rit.edu



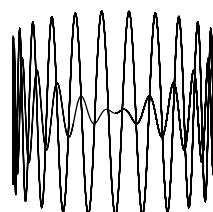
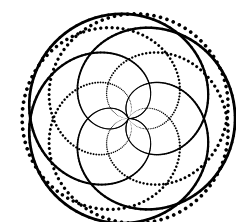
Imagine a pendulum with a pencil at the bottom, drawing its path on a piece of paper. You can also visualize a pendulum at the end of another pendulum drawing more complex figures. The shapes of such figures can be described by mathematical formulas. Basically these are oscillations, one along the X-axis and the other along the Y-axis. Mathematically, these oscillations are sine and/or cosine functions. The paths traced are known as Lissajous figures, named after the French mathematician Jules Antoine Lissajous. There are many ways that such figures can be generated. You can find others with a search of Google or Wikipedia; also checkout "spirograph."



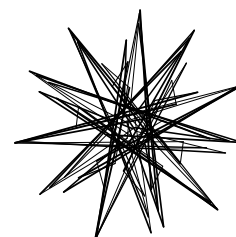
The figures in this document were made using handwritten PostScript code. The program is an EPS file that can be distilled to make a PDF which then can be viewed or printed from Adobe Acrobat. The EPS file can be opened in a text editor and variables in the header of the file can be set in order to obtain different figures.



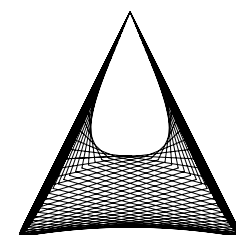
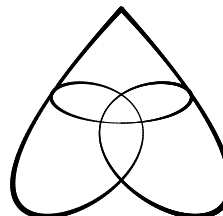
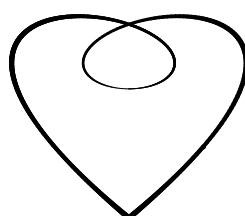
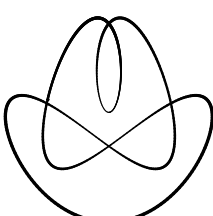
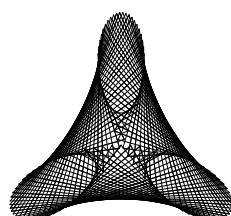
The EPS file is letter size which can be changed in a program such as Adobe Illustrator or InDesign. At the bottom of the page, the program writes down the parameters that were used for the figure. This way similar figures can be regenerated by using similar parameters.

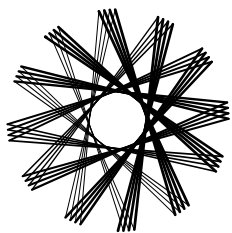
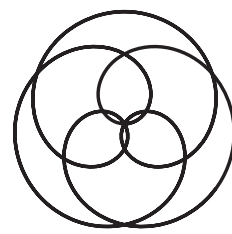
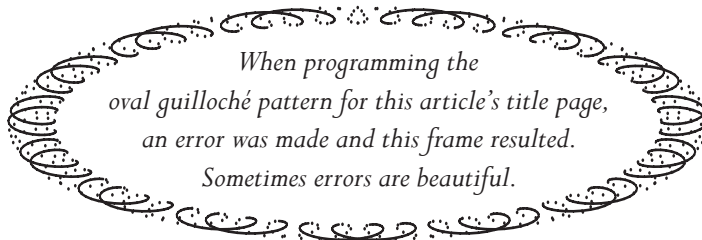
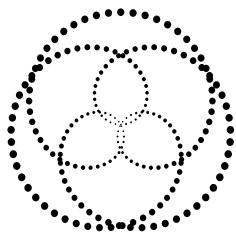


Four Pattern Factors are used to determine the shape. Any four numbers can be used, but keeping integers as simple ratios makes for more symmetrical and harmonious figures.



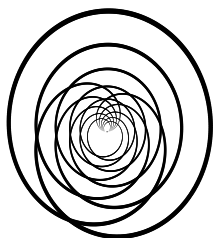
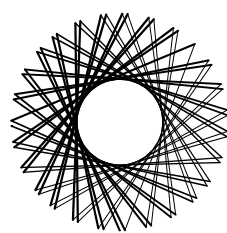
The figures are actually composed of many straight lines that are connected together. Line length is a user settable variable.



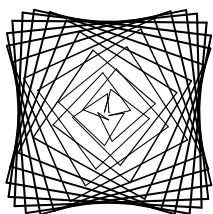
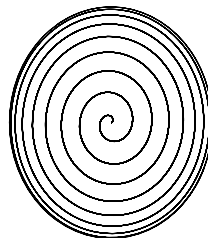


Short lines make for figures with apparently smooth paths. Longer lines make for interesting effects that would not be obtainable with a pendulum.

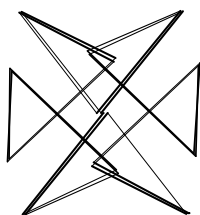
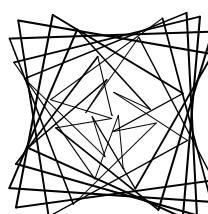
One variable can be set so that the lines near center are automatically painted thinner than the ones farther away. This gives a calligraphic effect.



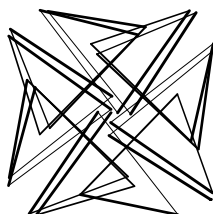
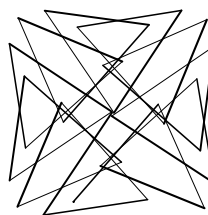
A real pendulum has friction, and therefore the painted paths become smaller and smaller. This effect can be simulated by setting a friction factor of less than one. Numbers such as 0.9995 work well. The friction factor is used to multiply each consecutive painted line, and therefore the lines get shorter and shorter.



The program would run indefinitely unless some limit is set. There is a parameter that defines the maximum number of lines. Another way to terminate the program is to set the number of cycles. A cycle is the path in the figure that it takes to return to the starting point in the center of the figure. If the number of cycles is set too high, then the path may repeat itself and therefore lines are unnecessarily painted on top of one another. If the number is set too low, then the figure is not fully drawn. Limiting the number cycles has the advantage that the end of the path will always be at the center of the figure.

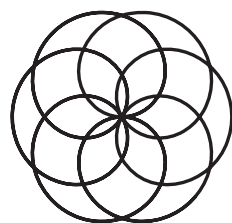
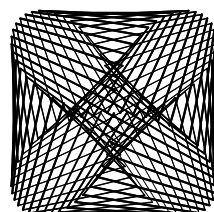
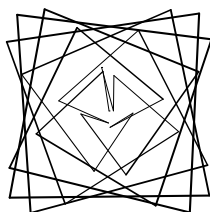
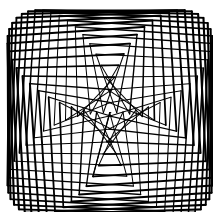
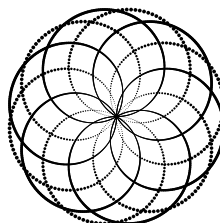
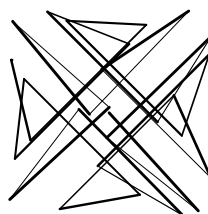


The program can paint dots instead of lines. The line length parameter defines the distance between the dots, and the line width defines the radius of the dots.



Many more possible figures can be made with this program. You can explore them by downloading the EPS file and documentation from:

<http://cias.rit.edu/~gravure/cms/tools.html>





# Non-CMYK Pictorial Color Image Reproduction

Robert Chung  
rycpr@rit.edu

## 1.0 Introduction

Rules, sometimes, are meant to be broken. For example, printing freshmen learn that lithography works based on the principle of “ink and water do not mix.” By the time they are seniors, they learn that emulsified ink is necessary in order for a lithographic press to function properly. After all, ink and water do mix.

Any printing student or professional will admit that a golden rule in pictorial color image reproduction is that process color or CMYK inks should always be used. To challenge the rule, one must ask the question, “Can pictorial color images be repro-

duced using non-CMYK inks?”

Figure 1 illustrates a pictorial color reproduction of a camel scene. Upon examining contents of interest in the image, everything looks normal, i.e., a person in white dress riding on the lead camel crossing desert sands.

Figure 2 shows that red ink (upper right), green ink (lower right), and blue ink (lower left) make up the color composite (upper left). If this is not convincing enough, you can examine the color composite with a loupe.



Figure 1. A pictorial color image reproduced by non-CMYK inks



## 2.0 Reproducing Pictorial Color Images

Achieving pictorial color image reproduction using non-process inks follows the same concept as using process inks, i.e., (1) color printer characterization, (2) color conversion, and (3) color printing. Color printer characterization defines the relationship between device color signals and CIELAB values. Ordinarily, CMYK colorants are chosen for their ability to achieve large color gamut. When characterizing non-CMYK printing device, the key criterion is the ability to render color of interest as oppose to achieve large color gamut. In the color conversion stage, pictorial images are converted from the RGB color space to the printer space via an Application Programming Interface (API). In the color printing stage, color-managed images are printed in registration using the inks that characterize the color printer.

## 3.0 Tools and Materials for Reproducing Color Images Using Non-CMYK Inks

Special software and hardware are necessary to implement pictorial color image reproduction using non-process inks. First, X-Rite's ProfileMaker 5 MultiColor Package is used to define a special color characterization target. In this case, three Pantone colors (32\_red, Hex\_green, and 2925\_blue) are printed by an HP Indigo 5500 digital press capable of printing CMYK plus three spot colors (Figure 3a). X-Rite's Spectrolino/Spectroscan is then used to measure the printed target. Colorimetric data was used by ProfileMaker 5 to build a custom spot-color ICC profile.

X-Rite's Multicolor Plug-In for Adobe Photoshop serves as the API to convert pictorial RGB image data to non-CMYK color space (Figure 3b). In this case, Perceptual rendering is chosen in the color



Figure 2. Red, green, and blue inks make up the color image

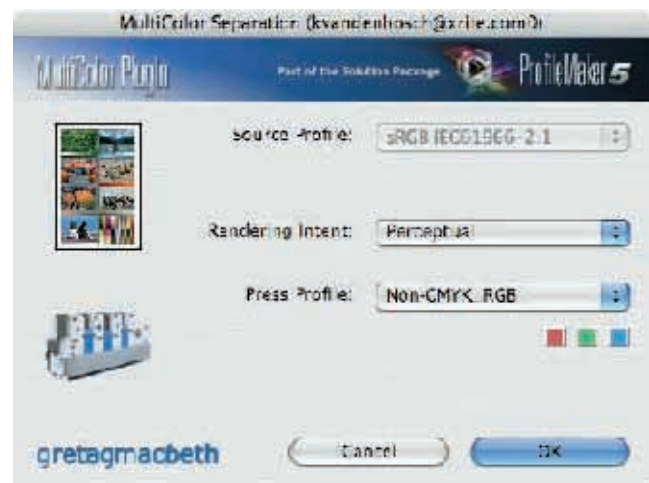
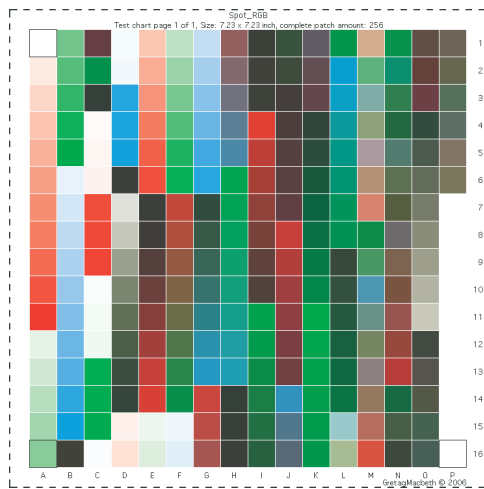


Figure 3. Color printer profiling target (3a; left); and MultiColor Photoshop Plug-In (3b; right)

conversion. Converted images are saved as EPS files and placed in the InDesign file. The InDesign file is exported as a PDF file for color printing. Color printing using non-process inks involves printing the same way the spot-color characterization chart is printed.

#### 4.0 Process Color Gamut and Non-process Color Gamut

Process color inks and Pantone certified spot-color inks are transparent in nature. When overprinting different amounts of inks, the resulting color follows subtractive color mixing principle, i.e., starting from white paper, the more inks are overprint-

ed, the darker the printed color becomes. Color gamut refers to limiting colors that an imaging device can render. CMYK-color gamut has generous volume. Non-process color gamut, on the other hand, has small gamut volume.

Using the ProfileMaker 5 tool set, Figure 4 compares the color gamut between the HP\_CMYK and HP\_RGB in 2D (4a; left) and 3D (4b; right) respectively.

In Figure 4a (left), the black line is the boundary of the CMYK color gamut of the HP 5500 digital press and the white line is the boundary of the

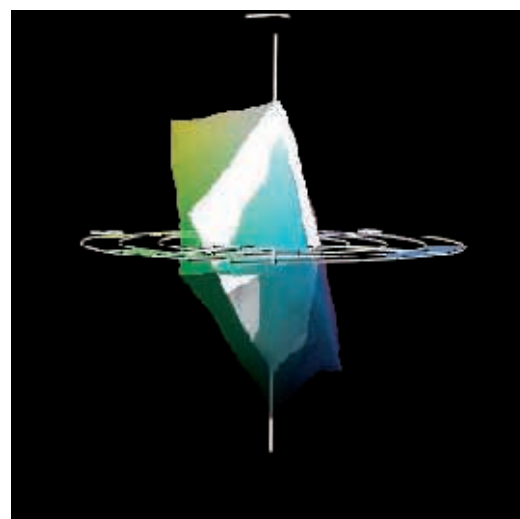
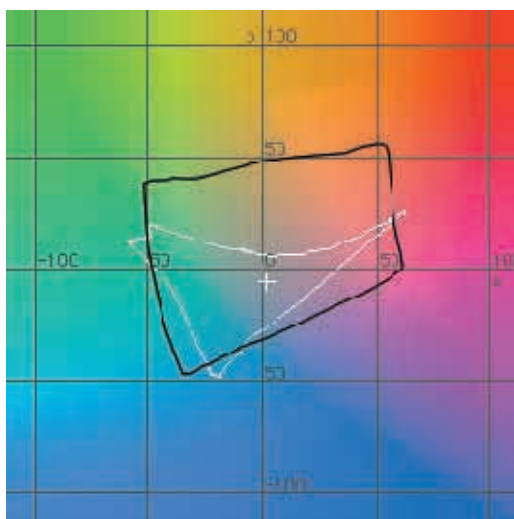


Figure 4. Color gamut comparison between the HP\_CMYK and HP\_RGB. 2D (4a;left) and 3D (4b; right)

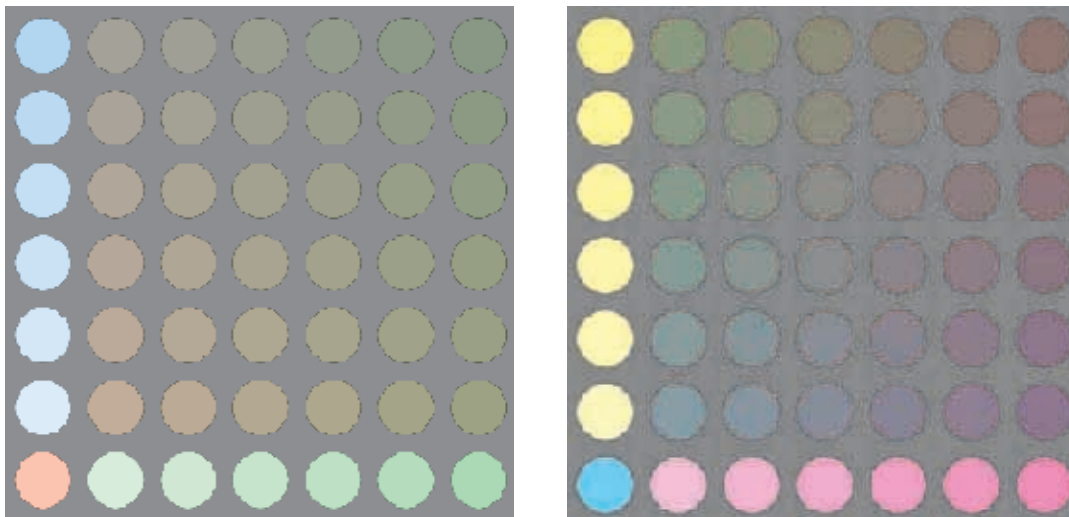


Figure 5. Gray balance from RGB inks (5a; left) and CMYK inks (5b; right)

RGB spot color gamut at medium  $L^*$  level. While its color gamut is smaller, the non-process inks have more saturation towards their primaries, i.e., redder red, greener green, and bluer blue.

In Figure 4b (right), the color-rendered solid is the CMYK color gamut of the HP 5500 digital press and the white solid is HP 5500's RGB spot-color gamut. Notice that whites and grays are reproducible by either printing process. While CMYK color gamut can accommodate the reproduction of yellows and oranges, the RGB color gamut can be an effective color reproduction process if (1) non-process inks, e.g., red, green, and blue, are already used as brand colors, and (2) color of interest in the pictorial color image is reproducible.

### 5.0 Seeing is Believing

Let's evaluate the gray balance chart, printed by the HP\_5500 RGB inks (Figure 5a; left) as well as by the HP\_5500 CMYK inks (Figure 5b; right). Notice that all patches in Figure 5a have a constant red dot area with green dot areas varying column-wise and blue dot areas varying row-wise. Similarly, Figure 5b has a constant cyan dot area with magenta dot areas varying column-wise and yellow dot areas varying row-wise. If there is a color match in neutral, the match between the two ink sets is metameric, i.e., two objects have the same color, but have different spectral reflectance values.

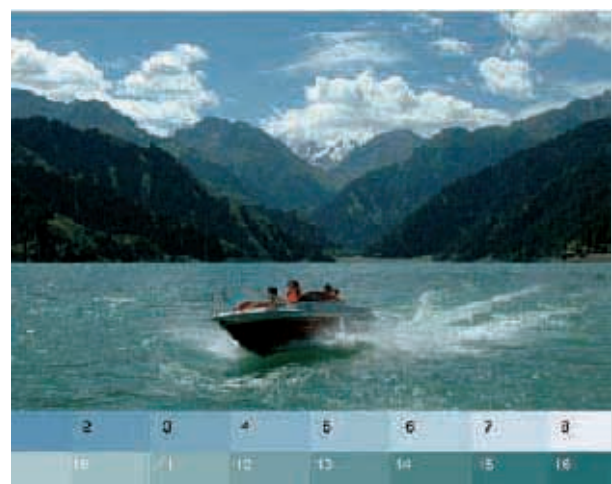


Figure 6. Pictorial color reproduction of memory colors using non-CMYK (6a; left) and CMYK (6b; right)





Figure 7. Pictorial color reproduction of non-memory colors using non-CMYK (7a; left) and CMYK (7b; right)

Let's evaluate an example of color reproduction, Boating, with memory color (Figure 6). Blue sky, white cloud, and turquoise water are colors we can associate with the beauty of nature. When these colors are reproduced in a pleasing manner, it does not matter if non-CMYK inks (Figure 6a; left) or CMYK inks (Figure 6b; right) are used.

Let's evaluate an example of color reproduction, Glazed Ceramic Pots, without memory color (Figure 7). First, a ceramic pot can be any color. So, there is no memory color that can serve as a visual reference. Without a loupe, how would one recognize which printing process is used to reproduce which image? Well, the answer lies in the color gamut capability of the ink sets. Figure 7a (left) has more saturated green and Figure 7b (right) has more color rendering capability in the yellow region of the color gamut. Thus, Figure 7a (left) is printed by non-CMYK colors while Figure 7b (right) is printed by CMYK colors.

## 6.0 Conclusions

This article shows that pictorial color images can be reproduced with CMYK inks as well as non-CMYK inks. Process color or CMYK printing provides a large color gamut in comparison to other 4-color subtractive primaries. This enables hues in all pictorial color images to be reproduced. This is also a liability because the color variations are likely to occur in the color printing stage if there is

no strict process control measure.

Non-process colors are primarily used as brand colors as dictated by consumer product companies. Because of the advances in color management, it is possible to render pictorial color image reproduction if colors of interest in the image and the spot color gamut are compatible to each other. One example is to use spot colors to decorate contemporary building materials with wood grains or marble patterns. By carefully selecting spot colors that cover a small range of colors of interest, the color reproduction process is much more stable than CMYK color printing. Each has advantages and disadvantages. The choice lies in the customer's need and technology fit.

# Design and Printing with the MetalFX System

## The Application of MetalFX in *Test Targets 8.0*

Michael Riordan

[mprppr@rit.edu](mailto:mprppr@rit.edu)

### 1.0 Introduction

MetalFX Technology's system utilized on the cover and throughout this publication exemplifies the concept of overprint through the use of a metallic ink printed underneath the standard CMYK process colors. While the concept is hardly a novel one, the MetalFX system is unique in that, through its integration with standard graphic arts software and workflow, it enables the direct specification of a broad palette of metallic colors.

#### 1.1 About the MetalFX system

MetalFX is a metallic color printing system that specifies standard metallic ink and then overprints the CMYK process colors to achieve a wide gamut of metallic colors (see Figure 1 and 5). The process works on the basis that the CMYK inks are transparent and, when printed on top of metallic ink, will create a full-color palette of metallic colors. When run to standard densities, these colors can be specified in premedia and design software in the same manner as other custom or spot colors.

### 2.0 MetalFX in the Context of *Test Targets 8.0*

We're using the MetalFX system to design and print the cover and several of the interior pages of *Test Targets 8.0*. From the technical perspective, the inclusion of a metallic ink provided for an opportunity to test the software, production workflow, and printability of the MetalFX system. From a design perspective, we were also curious to see the visual impact a metallic ink would have on the appearance of the publication.

The MetalFX software functions like a plug-in to most graphic arts software applications. The installation process brings in a full palette of MetalFX color swatches based on the MetalFX silver and gold metallic inks and also installs "Actions" within each software application to enable automatic conversion of CMYK files to CMYK + MetalFX Base Silver or Base Gold. MetalFX's metallic colors are added as a swatch book to each software's exist-



Figure 1. On the left is CMYK only and on the right is CMYK + MetalFX Silver. Can you see the difference?

ing libraries, enabling designers to select specific metallic colors the system can render. Along with the swatches, Actions are added to enable the easy implementation of the MetalFX system with vector and raster graphics.

Once the 5-color (CMYK + Silver or Gold) has been created, metallic inks, supplied by Eckart America, are used for the print production of the MetalFX colors. The model of using a single metallic ink to specify and accurately produce the full range of the MetalFX palette is fully enabled when



3. The transparency of the color element may be adjusted via the 'Opacity' setting under the 'Normal' blending mode. A gradient may be applied to any of the MFX colors and the silver base.
4. Go to View and select "Overprint Preview" to allow the monitor display to simulate the overprint effect.
5. Generate a PDF (high quality, PDF 1.5) to verify the CMYK and spot-color channels are present and that the appearance of the design in Adobe Acrobat with Overprint Preview and Output Preview enabled are correct.



*Figure 2. Two monochrome images were selected to show the impact of MetalFX. The negative leaf image was divided in half, with CMYK on the left and MetalFX (CMYK + Silver) being applied to the right side only. The fish image was masked out to leave the sand CMYK and apply MetalFX (CMYK + Silver) to the fish only.*

a print service provider has gone through the off-set printer certification process.

For the TestTargets 8.0 cover, MetalFX was applied through Adobe Illustrator CS3 to vector-based illustrations. The procedure followed is documented below:

1. Start with a CMYK file of the design. Assign MFX swatch color numbers to design elements via MFX Swatch Library, including a MFX silver base as the base layer.
2. Go to Window/Attributes and check the Overprint Fill (or Overprint Stroke) box for the color element that is on top of the metallic color so that the metallic ink will not be knocked out.

The process for creating the pixel-based images within this article followed a similar workflow, but with a few exceptions. Instead of specifying color swatches, the full gamut of each CMYK image was utilized. Secondly, to apply MetalFX, a simple Adobe Photoshop Action was "played" on each image file (Figure1 to 6). Finally, for several image files, a mask was created to allow the application of the MetalFX system to portions of the image rather than the entire image. Look to the captions of Figures 2 and 3 for details.

### 3.0 Proofing and Printing MetalFX Designs

Soft-proofing the MetalFX effect provides several challenges. While the color gamut of the MetalFX palette falls within the reproducible gamut of most monitors, the specific manner in which a file is



viewed is critical. As noted above, for PDF generated through Adobe Illustrator, the Overprint Preview function of Adobe Acrobat is required to gain an accurate view of what the file should render like. Files generated using Adobe Photoshop and other graphic arts software maintain the same Overprint Preview requirement. The view both with and without the Overprint Preview function on is illustrated in Figure 4.

Hard-copy proofing of MetalFX design is limited as it requires a system that includes metallic colorants in addition to CMYK.

For the printed production of MetalFX in *Test Targets 8.0*, the recommended ink sequence and densities were adhered to. Those specifications stated

that the metallic silver ink is printed as the first ink down, followed by KCMY process inks. The recommended CMYK solid ink density aim points for coated paper are Cyan 1.35, Magenta 1.40, Yellow 1.00, and Black 1.75. The tolerance for CMYK SID is  $\pm 0.10$ . The recommended silver solid ink density is 0.45-0.50 without a polarized filter or 0.70 with a polarized filter.

### 3.1 Seeing is Believing

The addition of a single metallic ink to the standard CMYK process colors increases the number of colors that can be reproduced and offers a range of potential benefits resulting from the visual impact provided by the metallic effect. The measure of that impact is subjective in nature and the il-



Figure 3. Some image content will be more appropriate for the application of MetalFX. The image of the fishing net on the left should display the MetalFX advantage in the lighter tones. On the right, the model's scarf was masked out to isolate the MetalFX to the green scarf only. The background and model's skintones are reproduced with only CMYK.

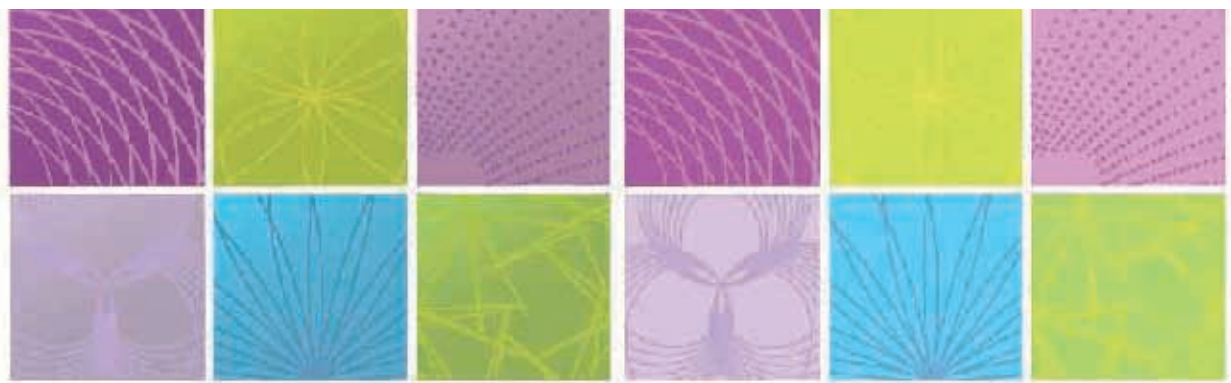


Figure 4. The Overprint Preview function in Adobe Acrobat allows for a more accurate display on color. Here, a section of the Test Targets 8.0 cover is shown with Overprint Preview “On” (left) and “Off” (right).



Figure 5. The image on the left reproduced CMYK + MetalFX Silver. On the right is an image of the “bump plate” MetalFX Silver produced by the Adobe Photoshop Action used to create this 5-channel image file.

illustrations within this publication are designed to give the viewer an introduction to the potential benefits of the MetalFX system.

#### 4.0 Conclusions

While the overall benefits of implementing the MetalFX may be hard to measure, its utilization during the production of *Test Targets 8.0* demonstrated that, while the production workflow presents some unique challenges, the MetalFX system is both easy to implement and provides a diverse range of opportunity for technical and marketing research.



Figure 6. While implementation of the MetalFX system in Adobe Photoshop is easily accomplished through the use of predefined Actions provided by MetalFX, each of the MetalFX Actions creates a very different effect. The image on the right illustrates the result of one of these actions applied displayed over the green scarf. To contrast, the image on the left follows the workflow of the *Test Targets 8.0* cover, with CMYK for the image and a solid layer of MetalFX Silver underneath.

# TEST FORMS



# Test Form Descriptions



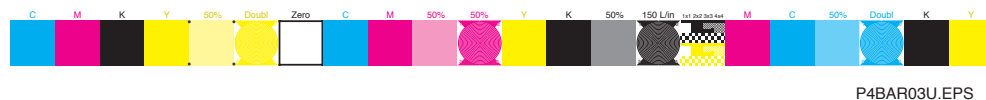
Test Forms is a collection of test targets arranged in a logical manner with known input values, e.g., CMYK values or resolution setting. It is output to a print production process. In previous issues of *Test Targets* publications, test forms were included without any description. Starting with *Test Target 8.0*, a description of the each test form is included to facilitate their use. Test forms are needed when studying prepress and printing process control and color management.

Most of the test forms in this collection share a common layout, e.g., color control bars are arranged in two orientations. Color control bars are designed to test the uniformity and consistency of ink density in both the machine direction (MD) and cross-machine direction (CMD). For more information about the control bar, refer to the *Test Targets 2.0* (Feb, 2002): Test Targets Showcase: The Common Elements.

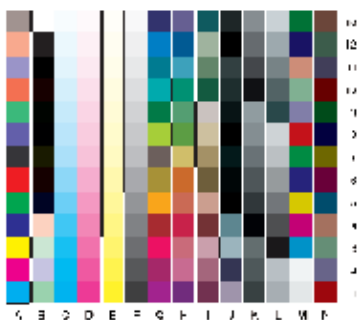
Each test form is described in terms of its layout, purpose and key features, i.e., design intent and functionality are explained in the following order:

1. Tone and Color
2. Pictorial Color Reference Images (CMYK)
3. Screening
4. Neutral Determination
5. Total Area Coverage (TAC)
7. IT8.7/4 Visual and Random
8. Spot-Color Ink Sequence (Offset & Digital)
9. CMYK Ink Sequence
10. Monochrome

The Test Form section is a regular feature in each year's *Test Targets* publication. For *Test Targets 8.0*, two new test forms are added: CMYK Ink Sequence and Spot-Color Ink Sequence. There are also two technical papers in *Test Targets 8.0*: "Effect of Ink Sequence on Offset & Digital Printing" and "Predicting Color of Spot Color Overprints, A Quantitative Approach," utilizing these two test forms extensively.







### Tone and Color

General description: This test form contains the basic block of the IT8.7/3 profiling target (CGATS, 2005) which consists of 182 color patches with known CMYK values.

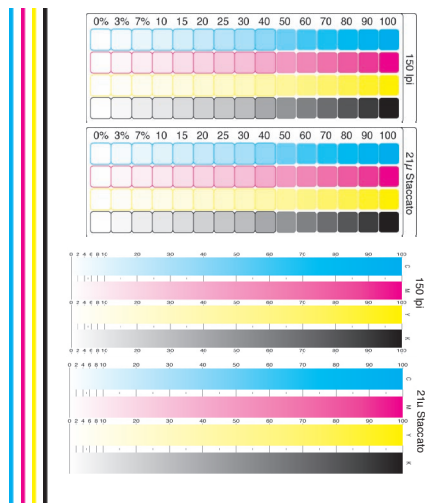
Key features: The IT8.7/3 basic block can be used to evaluate densitometric and/or colorimetric response of any four-color printing process. It is used to study tonal response (dot gain or tone value increase) and simple color gamut of a CMYK device.



### Pictorial Color Reference Images (CMYK)

General description: The test form contains two pictorial SCID images (Standard Color Image Data): N4A (Wine and Tableware) and N7A (Three Musicians) from ISO 12640-1, *Graphic technology -- Prepress digital data exchange -- Part 1: CMYK standard colour image data (CMYK/SCID)*, 2005. They are designed to appraise printing process characteristic and performance in terms of color appearance of standard pictorial images.

Key features: N4A (Wine and Tableware) has a large neutral areas as well as a large distribution of pixels in highlights and midtone. N7A (Three Musicians) has skin tones and chromatic colors as seen the three females' clothing. These images provide visual feedback of how memory colors, such as metallic neutrals, skin tones, by various output devices.

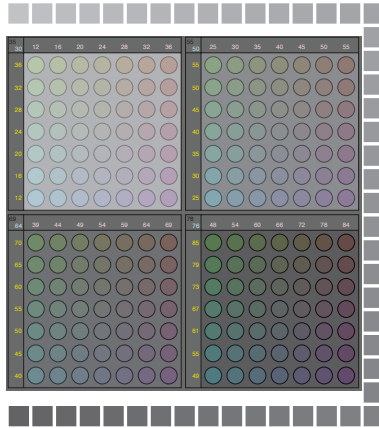


### Screening

General description: The screening test form contains step wedges and gradients with AM (150lpi) and FM (21 $\mu$  Staccato) screening. AM is a halftone screening method that renders an image with inked dots of equal distance, but varying in sizes to simulate the appearance of a continuous-tone image. In FM screening, halftone dots are created at a constant size; the number of dots in a specific area varies to create the appearance of a continuous-tone image. The screening test form is used to compare the differences between the two screening methods.

Key features: Upon printing the screening test form, they can be measured densitometrically to plot tone reproduction curves, or they can be measured colorimetrically to observe differences in chroma and TVI. The gradients are also useful for visual evaluation of the smoothness of tonal rendering and can be used to detect the minimal printable dot percentage. Screening is embedded in the (EPS) files and takes place at the time of ripping. Addressability of the output device should be 2,400 or 2,540 spi to actually obtain the indicated screening.

Dot-doubling grids are also included on the left side of the test form. Each color is composed of parallel lines in the vertical and horizontal directions. On the printing plate, the grids shows a uniform 50% tone overall. But if there is a directional distortion of the printed dots, the horizontal and vertical parallel lines will have different tone values. Good printing does not have directionally distorted halftone dots.



### Neutral Determination

General description: This test form includes two elements: CMY near-neutrals and K-only grayscale. It is used to determine the neutrality for a given ink-paper-printing condition.

Key features: CMY near-neutrals are divided into four tonal blocks. For each tonal block, the cyan dot area of the circles is constant while magenta dot areas vary by column and the yellow vary by row. The background of the circles is printed with black only to serve as a neutral reference. The CMY circle that fades into its neutral background indicates a unique CMY dot area combination that achieves gray balance. The K-only grayscale, situated around the CMY near-neutrals, has 1% dot-area increments. It is useful in determining a specific black dot area that matches the CMY neutral.

Paper	171	179	188	198	208	217	228	239	250	259
55 K	226	234	243	253	261	272	283	294	305	311
60 K	231	239	248	258	266	277	288	299	310	316
65 K	236	244	253	263	271	282	293	304	315	321
70 K	241	249	258	268	276	287	298	309	320	326
75 K	246	254	263	273	281	292	303	314	325	331
80 K	251	259	268	278	286	297	308	319	330	336
85 K	256	264	273	283	291	302	313	324	335	341
90 K	261	269	278	288	296	307	318	329	340	346
95 K	266	274	283	293	301	312	323	334	345	351
100 K	271	279	288	298	306	317	328	339	349	354

### Total Area Coverage (TAC)

General description: The TAC chart samples the shadow region of K-only and CMY near-neutrals combinations. It is used to determine (1) the darkest tonality produced by the dot-area combinations of CMYK, and (2) various TACs that produce the same darkness but at lower total dot areas. This chart supports ICC profile construction as well as some prepress optimization technologies such as Gray Component Replacement (GCR) and dynamic device link.

Key features: The TAC chart is a 10-by-10 step array. Each element in the array represents a known total area coverage of K-only and CMY near-neutrals. The TAC ranges from 226% to 356%. The K component varies by row from 55% to 100% with 5% increments. The CMY near-neutrals vary by column.

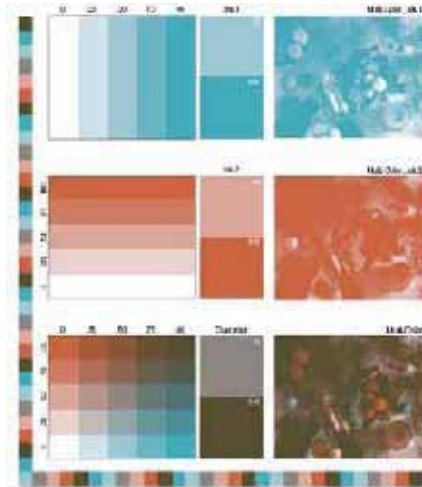


### IT8.7/4 Visual and Random

General description: The IT8.7/4 target contains 1,617 color patches with known CMYK values (CGATS IT8.7/4, 2005). This is an extended color chart from IT8.7/3 target that contains 928 color patches. The entire target dimension is larger than letter-size, when each patch size is 6x6 mm. It is used to characterize 4-color printing. The expanded data set aims to provide better sampling of the CMYK color space and to provide more data at the highlight end of the scale, including more 4-color data with low levels of black.

Key features: IT8.7/4 provides two target layouts: visual (top) and random (bottom). While the color patches in the visual layout are arranged systematically by tone values, patches in the random layout are situated without any systematic pattern in order to minimize the influence of the arrangement itself and possible non-uniformity of the printing device. However, for process control, 15 special patches are at a fixed location at the center of the target.



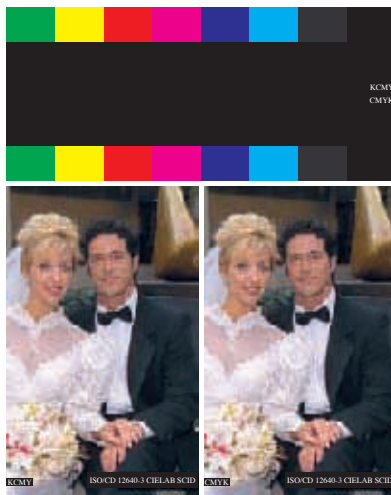


### Spot-Color Ink Sequence

General description: Spot-color inks can be transparent. A third color results when overprinting two spot-color inks together. While the current Adobe Creative Suite (CS3) allows a spot color overprinting on the other spot color (as opposed to knocking out non-surface colors), the software may not provide preview of the overprint color accurately. One of the difficulties is that there is no spot-color overprint information available in the color management system. This test form is designed to detect any overprint difference between press sheets printed from two spot-color ink sequences and from different printing devices.

Key features: There are three sections in the spot-color ink sequence test form: Multi-Color Ink 1 (top), Multi-Color Ink 2 (middle), and Multi-Color (bottom). As the name implies, Multi-Color Ink 1 is the first-down ink, Multi-Color Ink 2 is second-down ink, and Multi-Color is the overprint of Multi-Color Ink 2 on top of Multi-Color Ink 1. Black ink is used for labeling and captioning of the test form.

The pictorial color image in the test form is reproduced from an RGB image using X-Rite's GretagMacbeth ProfileMaker 5 Multi-Color package.



### CMYK Ink Sequence

General description: Most multi-color offset lithographic presses print process inks wet-on-wet in either CMYK or KCMY sequence. This test form is designed to learn if there is any tone and color difference between press sheets printed from the two ink sequences. While there is only one test form, it is printed using a press with five printing units whereby one black ink is situated in the first unit and the other black is situated in the fifth printing unit.

Key features: There are seven solid patches, GYRMBC, 3-color, and black, printed by cyan, magenta, and yellow inks in the top row. These patches are printed on top of the black ink in the KCMY sequence. The black ink is printed on top of CMY inks in the CMYK ink sequence in the second row. The spatial closeness of these overprint patches, printed in two ink sequences, facilitates visual comparison as well as colorimetric analysis. A pictorial color image of a bride and groom, consisting of highlight and shadow details, printed under either ink sequence, allows visual comparison of image quality differences due to ink sequence.



### *Monochrome*

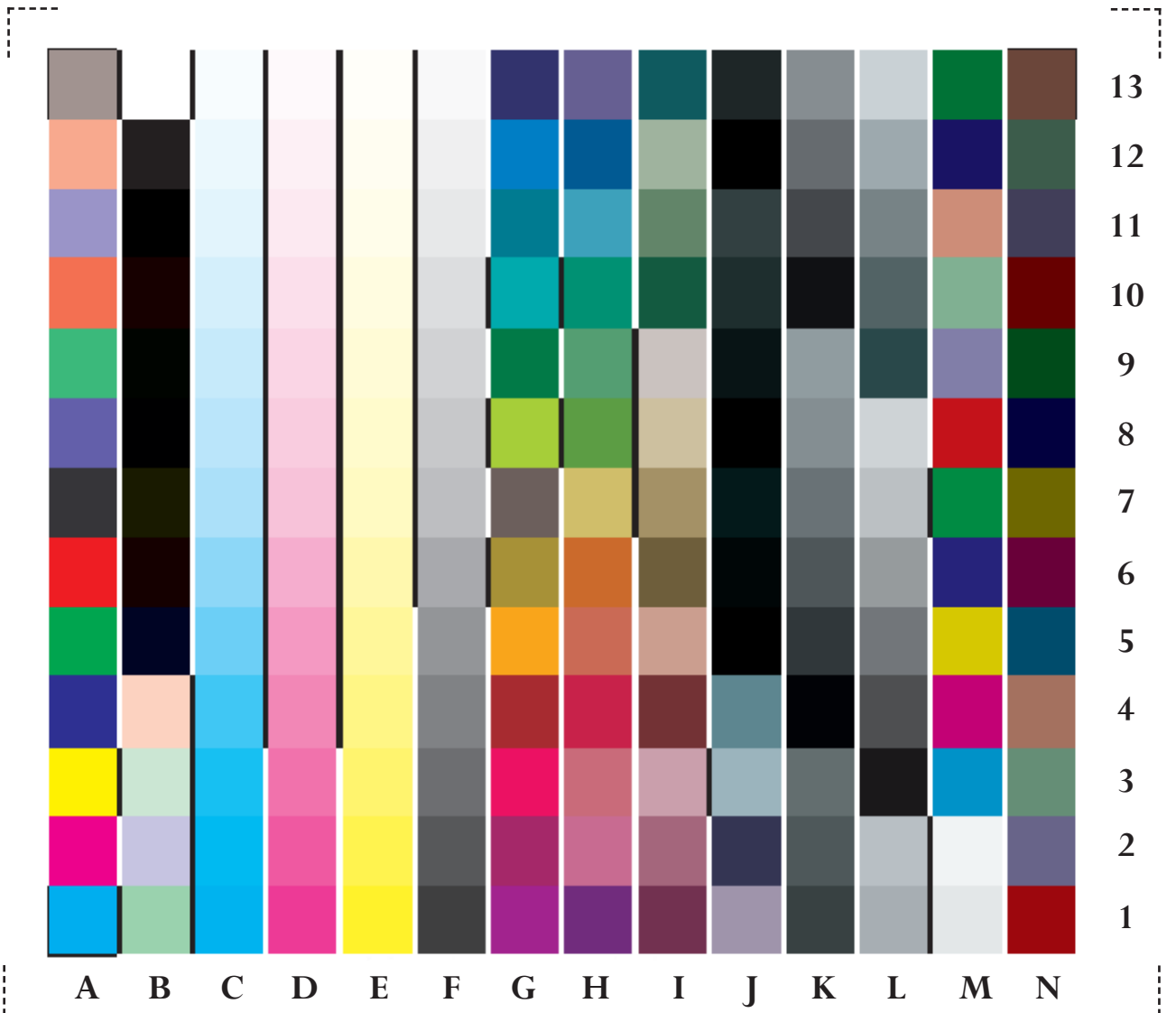
General description: The test form has two features: pictorial reference image and synthetic gray scales. It is useful to evaluate black-and-white printing for a given ink-paper-press condition and production tolerances.

Key features: Pictorial image N7A (labeled as A) is from “Pictorial Color Reference Images” (ISO 12640). It is converted from CMYK into monochrome in Adobe Photoshop. There are three gray scales: (1) The gray scale ranges (labeled as B1) from 0 to 100% with known dot area step-wise. By measuring or observing these steps, we can appraise the tone reproduction characteristic of a specific printer; (2) The gray gradient (labeled as B2) detects potential banding. Normally, it changes smoothly from highlights to shadows with no obvious banding and (3) 100-step gray scale with 1% dot area increments that are arranged into four rows to compose a very fine incremented gray scale (labeled as B3). It provides a detailed relationship between dot area and resulting density. If the measured tone reproduction curve is not smooth, this would be an indication of local non-uniformity of printing.

# Tone and Color

**Press** Heidelberg sheetfed offset  
**Paper** Sappi McCoy  
 100# gloss text, 19X25, grain long

**Premedia** Indesign CS3  
**Notes** Legacy CMYK  
**Prepress** Prinergy



IT8\_Basic\_iO.TIF



P4BAR03U.EPS

## Pictorial Color Reference Images (CMYK)

**Press** Heidelberg sheetfed offset  
**Paper** Sappi McCoy  
100# gloss text, 19X25, grain long

**Premedia** Indesign CS3  
**Notes** Legacy CMYK  
**Prepress** Prinergy



ISO 12640 N7A.tif



ISO 12640 N4A.tif



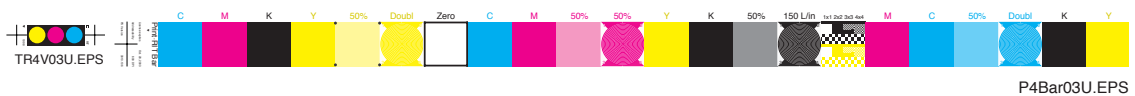
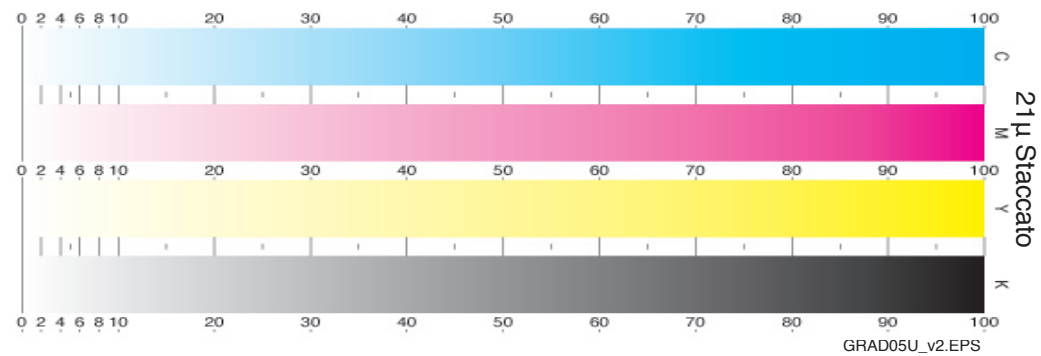
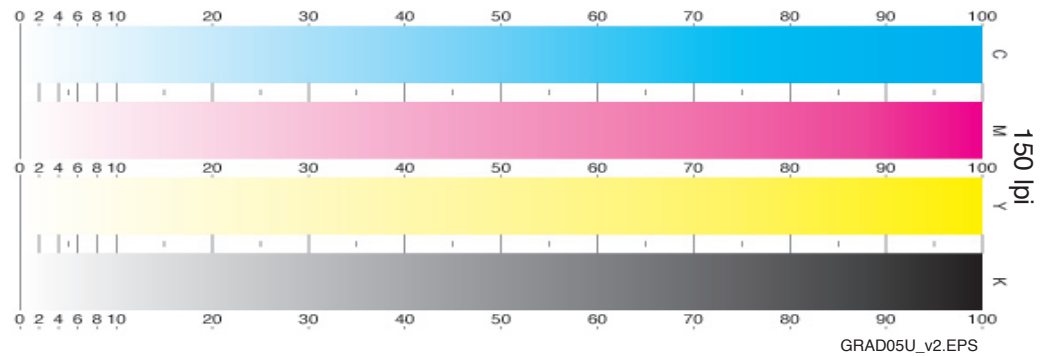
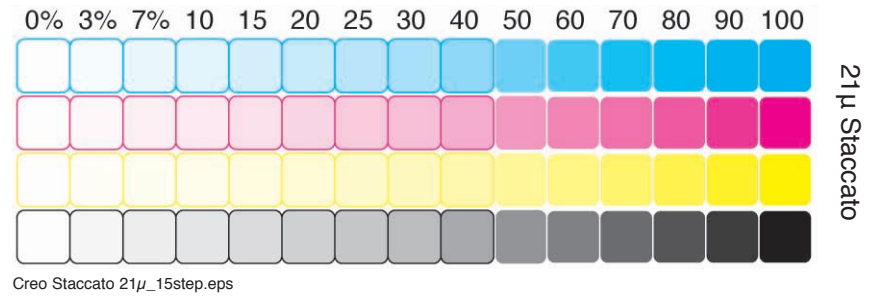
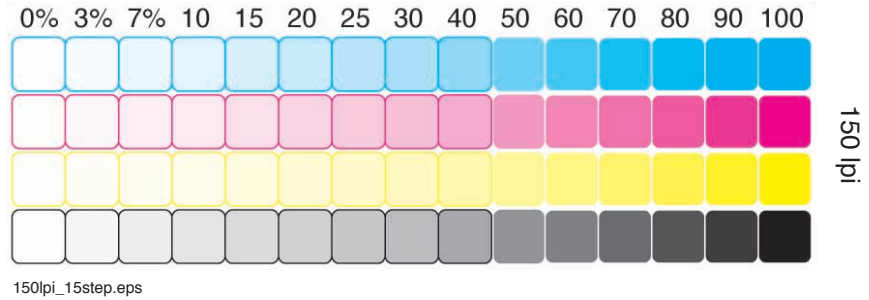
TR4V03U.EPS



# Screening

**Press** Heidelberg sheetfed offset  
**Paper** Sappi McCoy  
 100# gloss text, 19X25, grain long

**Premedia** Indesign CS3  
**Notes** Legacy CMYK  
**Prepress** Prinergy

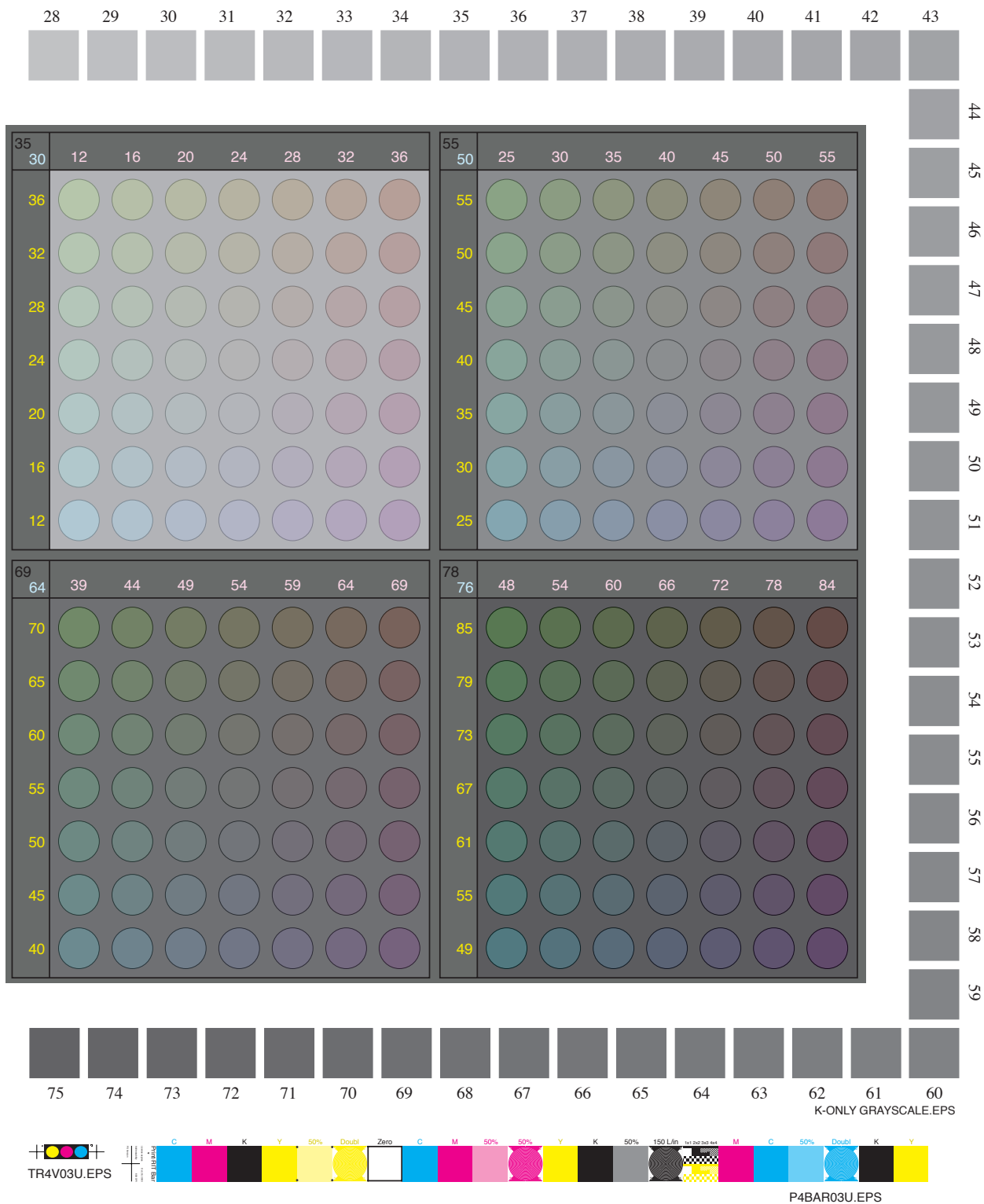




# Neutral Determination

**Press** Heidelberg sheetfed offset  
**Paper** Sappi McCoy  
100# gloss text, 19X25, grain long

**Premedia** Indesign CS3  
**Notes** Legacy CMYK  
**Prepress** Prinergy





# Total Area Coverage

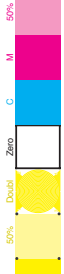
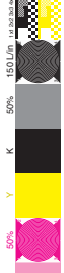
**Press** Heidelberg sheetfed offset  
**Paper** Sappi McCoy  
 100# gloss text, 19X25, grain long

**Premedia** Indesign CS3  
**Notes** Legacy CMYK  
**Prepress** Prinergy



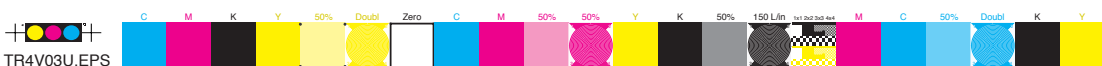
DG4CE11U.EPS

TR4V03U.EPS



	66 C	69 C	72 C	75 C	77 C	80 C	83 C	85 C	88 C	89 C
	53 M	55 M	58 M	61 M	64 M	68 M	71 M	75 M	78 M	81 M
	52 Y	55 Y	58 Y	62 Y	65 Y	69 Y	74 Y	79 Y	84 Y	86 Y

Paper	171	179	188	198	206	217	228	239	250	256	
55 K	226	234	243	253	261	272	283	294	305	311	10
60 K	231	239	248	258	266	277	288	299	310	316	9
65 K	236	244	253	263	271	282	293	304	315	321	8
70 K	241	249	258	268	276	287	298	309	320	326	7
75 K	246	254	263	273	281	292	303	314	325	331	6
80 K	251	259	268	278	286	297	308	319	330	336	5
85 K	256	264	273	283	291	302	313	324	335	341	4
90 K	261	269	278	288	296	307	318	329	340	346	3
95 K	266	274	283	293	301	312	323	334	345	351	2
100 K	271	279	288	298	306	317	328	339	350	356	1
TAC_CMYK(v1.4).tif	A	B	C	D	E	F	G	I	J	K	



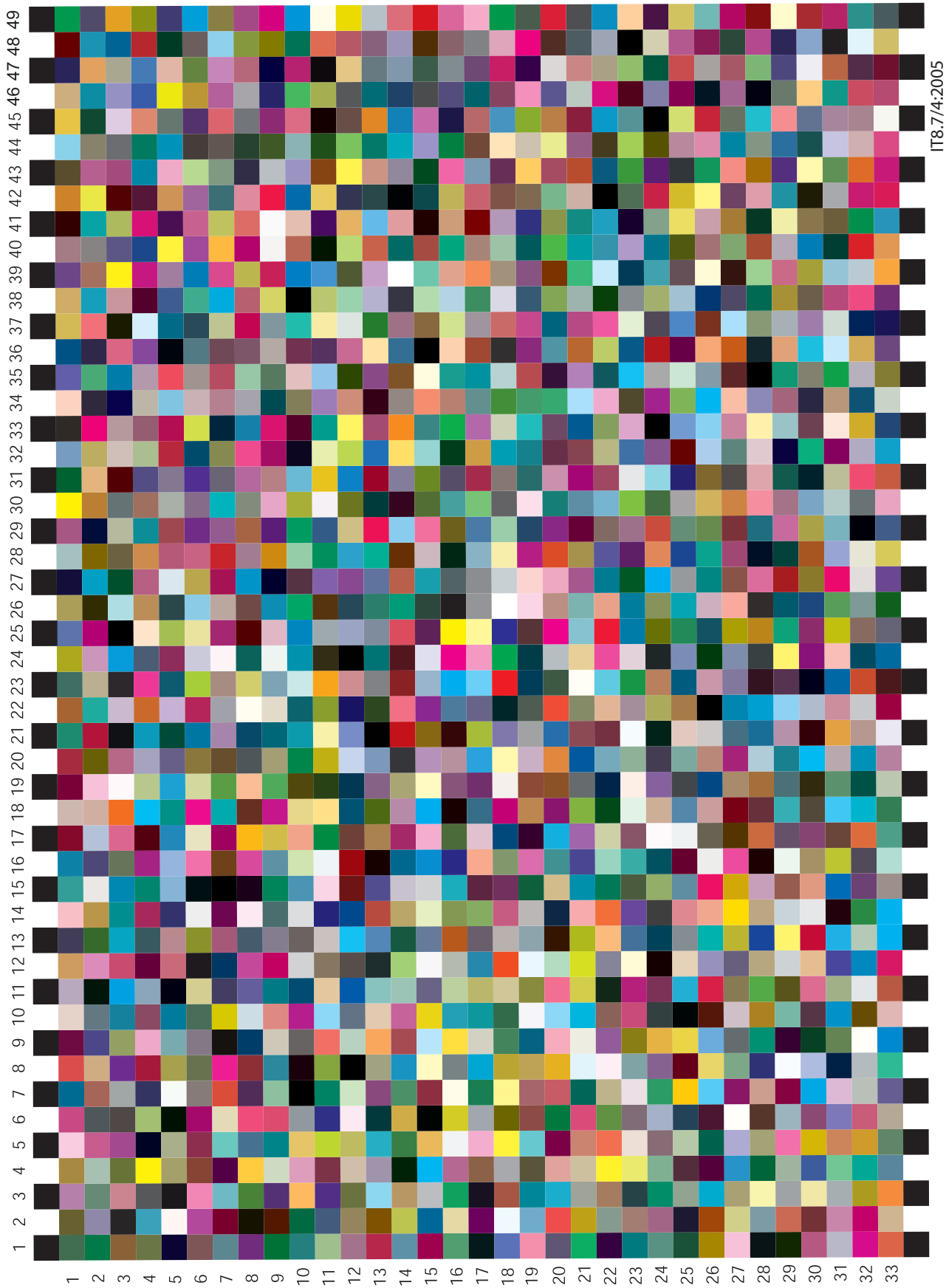
TR4V03U.EPS

P4BAR03U.EPS

# IT8.7/4-2005 Visual



IT8.7/4-2005 Random

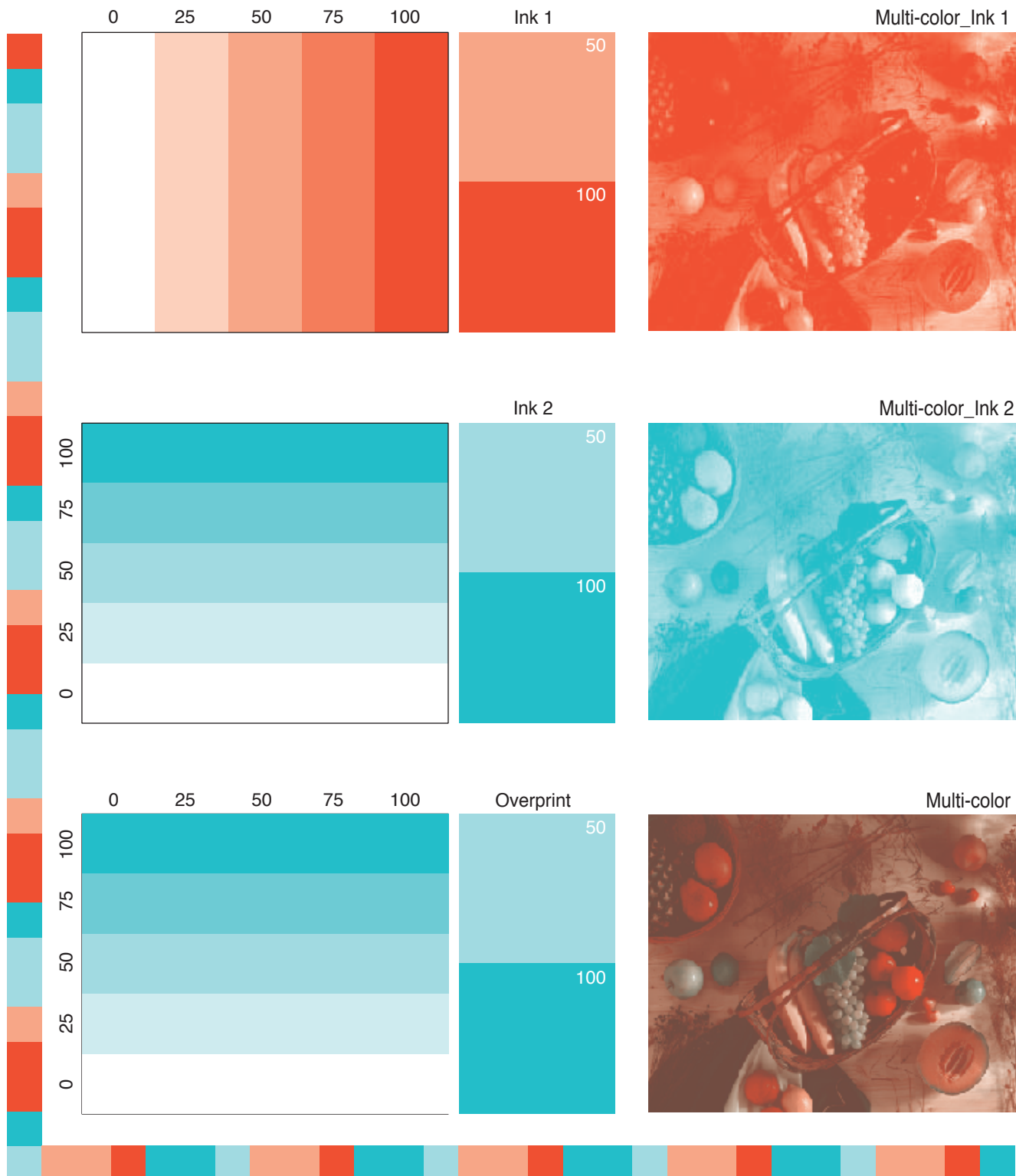


IT8.7/4:2005

# Spot-Color Ink Sequence: SM74

**Press** Heidelberg sheetfed offset  
**Paper** Sappi McCoy  
 100# gloss text, 19X25, grain long  
**Inks** 1788 C (red); 7466 C (turquoise); K

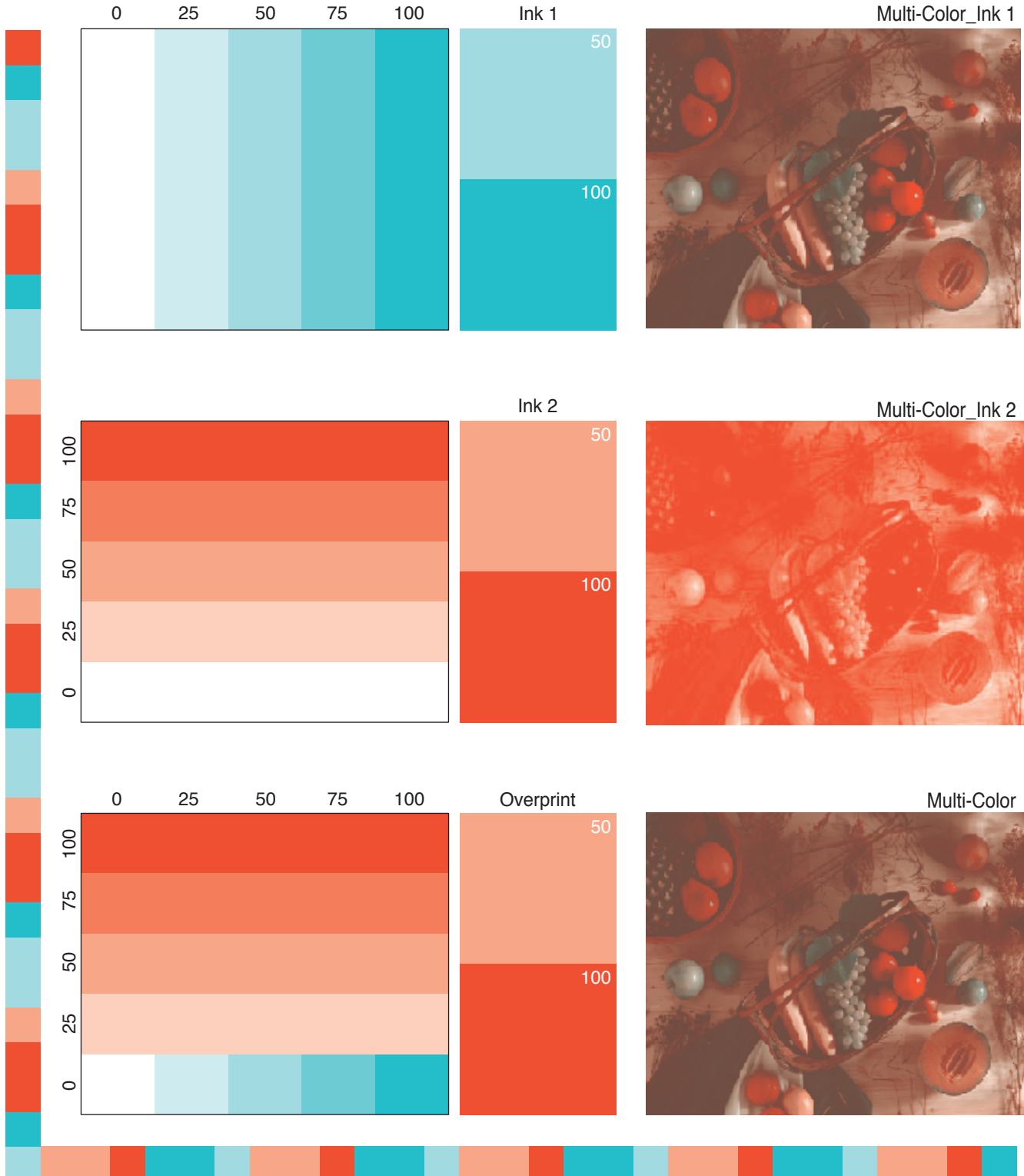
**Premedia** Indesign CS3  
**Prod. Notes** QA by PDF; Print by PDF  
 4 press units: spot 1, spot 2, spot 1, black  
**1<sup>st</sup> Ink down** 1788 C



# Spot-Color Ink Sequence: SM74

**Press** Heidelberg sheetfed offset  
**Paper** Sappi McCoy  
 100# gloss text, 19X25, grain long  
**Inks** 1788 C (red); 7466 C (turquoise); K

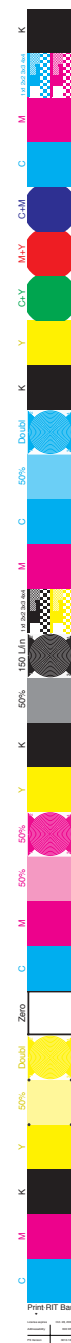
**Premedia** Indesign CS3  
**Prod. Notes** QA by PDF; Print by PDF  
 4 press units: spot 1, spot 2, spot 1, black  
**1<sup>st</sup> Ink down** 7466 C



# CMYK Ink Sequence

**Press** RIT - Heidelberg SM74 6 color  
**Paper** Sappi McCoy 100# Gloss Text  
**Inks** Kohl & Madden, SF-Marathon

**Inks** 1. K1:1MINBD0A2C Tack 17.4  
 2. C: 1MINBD000C Tack 13.8  
 3. M: 1MINBD02EO Tack 14.4  
 4. Y: 1MINBD0CD6 Tack 12.2  
 5. K2:BU97-1028A Tack 11.0





# Monochrome

**Press** HP Indigo 5500  
**Paper** Sappi McCoy  
100# gloss text, 12X18, grain long

**Premedia** Indesign CS3  
**Notes** Legacy CMYK  
**Prepress** Prinergy

100  
50



N7A\_GrayScale.tif

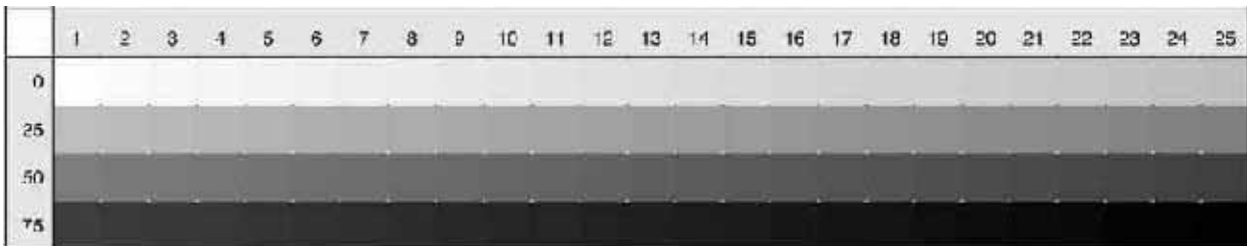
0 3 7 10 15 20 25 30 40 50 60 70 80 90 100

GrayScale.eps



0 2 4 6 8 10 20 30 40 50 60 70 80 90 100

GRAD04U\_Black.tif



100ST07U1\_Black.tif

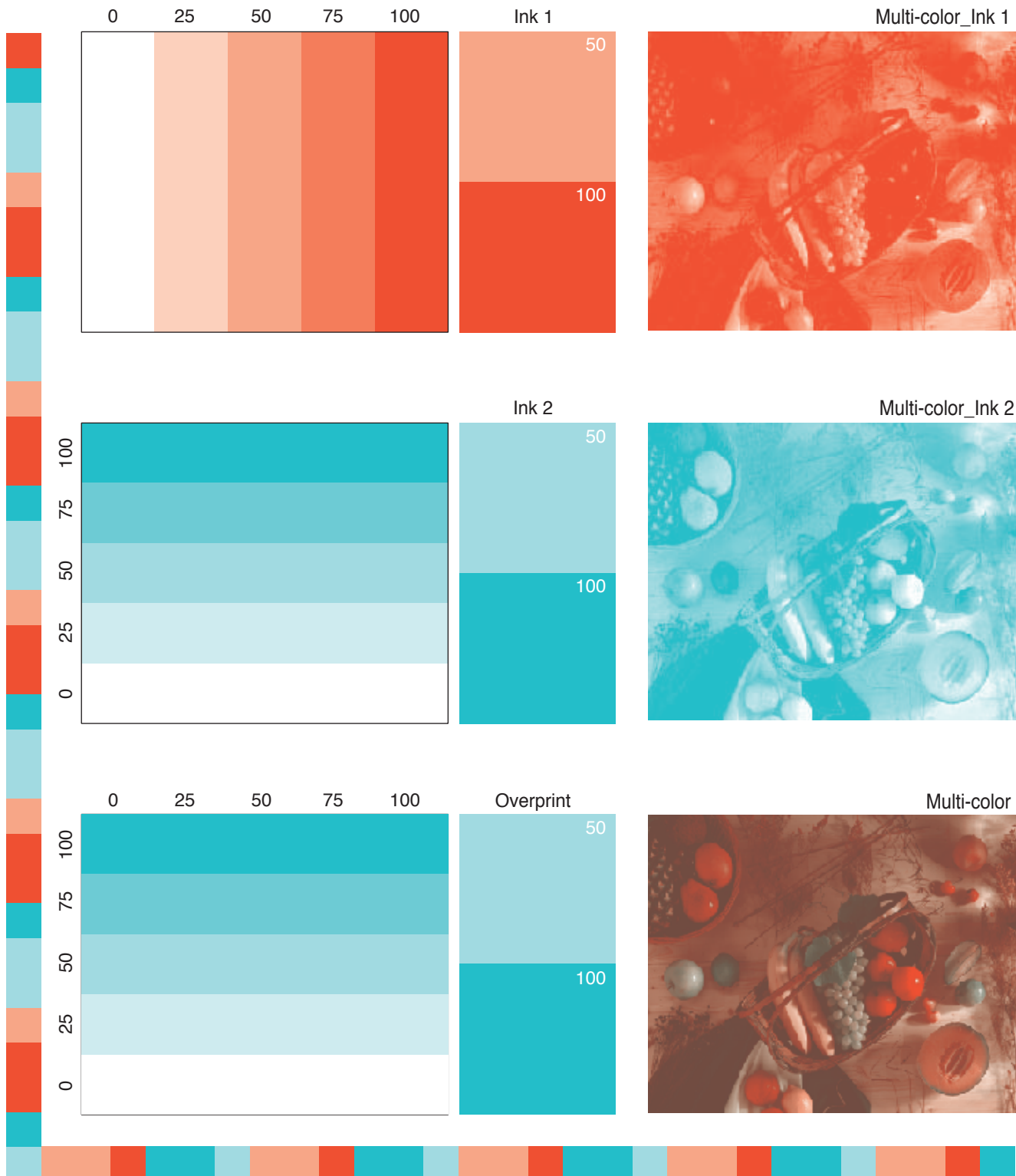
100 50

GrayBar.eps

# Spot-Color Ink Sequence: HP 5500

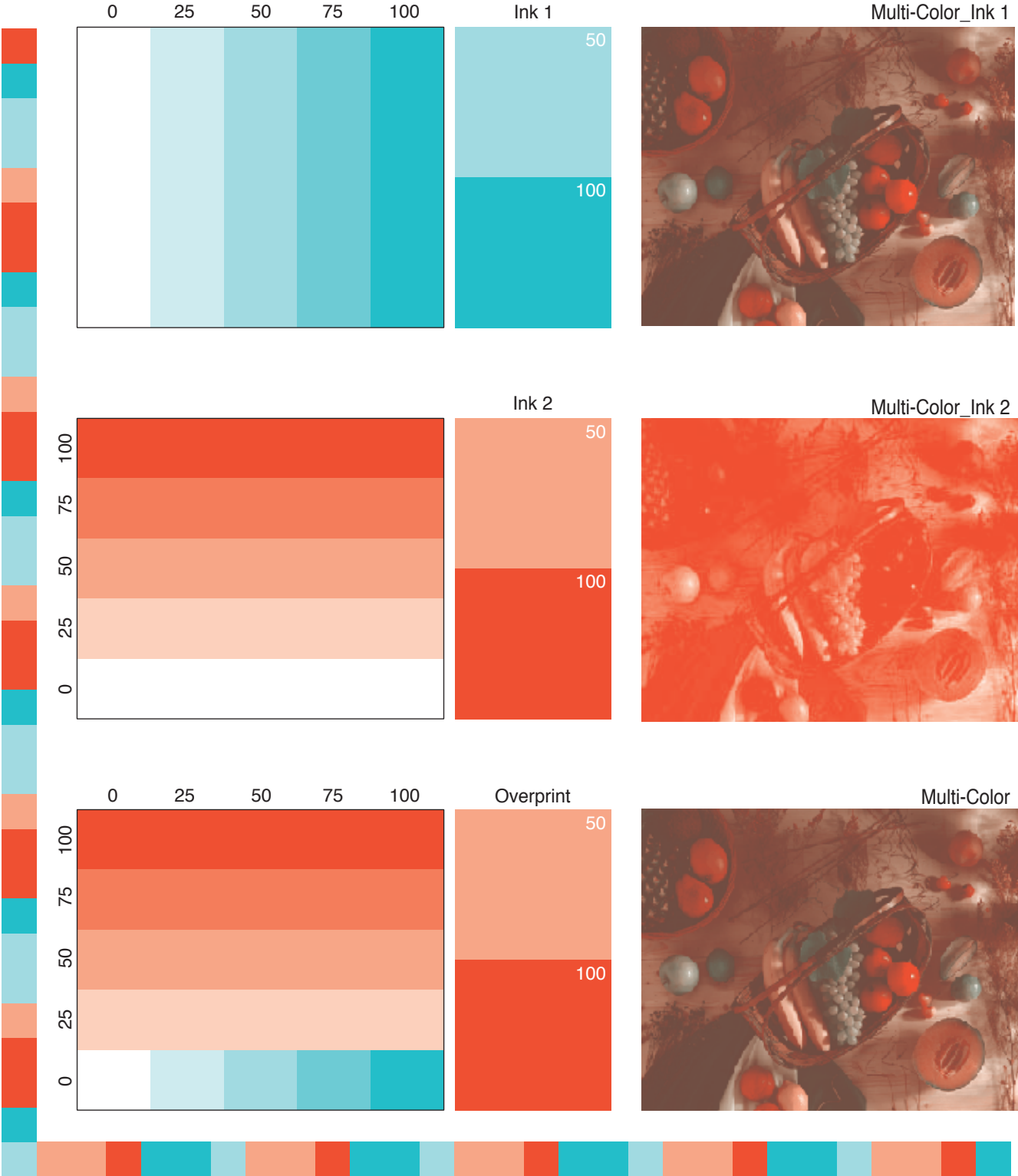
**Press** HP Indigo 5500  
**Paper** Sappi McCoy  
 100# gloss text, 12X18, grain long  
**Inks** 1788 C (red); 7466 C (turquoise); K

**Premedia** Adobe Illustrator CS3  
**Prod. Notes** QA by PDF; Print by PDF  
 4 press units: spot 1, spot 2, spot 1, black  
**1<sup>st</sup> Ink down** 1788 C



Spot-Color Ink Sequence: HP 5500

Press	HP Indigo 5500	Premedia	Adobe Illustrator CS3
Paper	Sappi McCoy	Prod. Notes	QA by PDF; Print by PDF
	100# gloss text,12X18, grain long		4 press units: spot 1, spot 2, spot 1, black
Inks	1788 C (red); 7466 C (turquoise); K	1 <sup>st</sup> Ink down	7466 C



FYI

### *HP Indigo Spot-Color Inks*

Spot-color ink is specially formulated ink as opposed to simulated CMYK inks. Spot-color ink requires a printing unit to print and it often produces more saturated color than its CMYK counterpart. *Test Target 8.0* takes a close look at how spot-color overprint behaves when printing by offset and by digital press. It also examines how spot colors may be used to reproduce pictorial color images using the 7-unit HP 5500 digital press. Here is the rest of the story, i.e., how spot-color digital inks are formulated. RIT Printing Applications Laboratory (PAL) has a full-fledged HP digital ink mixing facility. When spot-color ink is specified, either as a Pantone number or a physical sample, the operator verifies or measures its spectral reflectance characteristic. He or she then checks if there is an ink formulation in the color matching library. If the color formulation exists, the operator will make up the quantity of that ink using a precision scale and mechanical shaking devices. If it is a new color, the operator will (1) use the color matching software to come up with a recipe, (2) make a small batch of the ink, (3) use the HP 5500 digital press to print on a standard paper stock, (4) measure the printed color, and (5) enter the results into the color matching program. If the color is within tolerances, the operator can start to produce the batch as requested; else, the color matching software will provide a modified formula and the process iterates from Steps 2-5 until done.

(submitted by Bob Chung)

# COLOPHON





FYI

*Looking for Previous Test Targets?*

Many graphic arts topics of interest were explored and published in previous *Test Targets* publications. In terms of printing process control, we conducted process capability analysis of ink jet, electro-photographic, and offset printing processes; we examined pros and cons of color measurement metrics and their sensitivities in detecting inking variations. In the area of color management, we examined the effect of 'assigning' RGB profiles on the appearance of color reproduction; we demonstrated gradation match between AM and FM screening and gray balance match between two printing conditions; we demonstrated the use of device link profile to achieve color matching between a sheet-fed offset and a digital press. You can browse Test Targets online and download articles of interest as PDF free of charge at <http://cias.rit.edu/~gravure/tt/index.html>. To obtain a hard copy of *Target Targets*, you can visit the web store of the RIT Cary Graphic Arts Press at <http://library.rit.edu/cary/carypress.html>. The proceeds will go to the School of Print Media scholarship fund.

(submitted by Bob Chung)

# Acknowledgements

*Test Targets* is the collaboration among RIT and industry colleagues to explore and to publish lessons learned in color imaging and process control. We are grateful for the support and involvement of the following organizations and individuals.

The financial aspect of *Test Targets* was supported through the School of Print Media. The Executive Committee decided to enlarge the scope of *Test Targets 8.0* and sought additional support from the RIT Printing Industry Center to cover the salary of co-op students serving as project coordinators.

The Steering Committee did the planning, implementation of a server-based review and publishing workflow, and interaction with authors, graphic designers, reviewers, and support personnel.

It is the author who demonstrates the scholarship of applications that are enabled by technology partners and enhanced by technical and editorial review. It is the IT and the print production support that make document communication and printing possible.

## **Organizational Support**

RIT Printing Industry Center  
RIT School of Print Media

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Hewlett-Packard Company  
MetalFX Technology  
Sappi  
X-Rite, Inc.

## **IT and Print Production Support**

RIT Printing Applications Laboratory  
RIT College of Imaging Arts & Sciences

## **Cover Design**

Ching-Ping Chen, RIT

## **Project Coordinators**

Stephanie Pieruccini, RIT  
Jiayi Zhou, RIT

## **Authors**

Evan Andersen, RIT  
Khalid Husain, RIT  
Jiayi Zhou, RIT  
Robert Chung, RIT  
Michael Riordan, RIT  
Franz Sigg, RIT  
Bill Pope, FTA  
Fred Hsu, RIT

## **Videographer**

James Kase

# Press Run Organizer

## The Keeper of The Truth

### Introduction

Press Run Organizer (PRO), like a job ticket, is a communication tool between content owners and print providers. It organizes information in terms of what contents are to be printed, using what print media, with what screenings, what ink and paper, how many colors are involved in a signature, printing specifications, and imposition, etc. We create a PRO for each printing device used. In *Test Targets 8.0*, three PROs are included: one for the cover, one for the body of the text using the Heidelberg SM74 sheet-fed offset press, and one for the Gallery of Visual Interest section using the HP Indigo 5500 digital press.

### Unique Features in the Print Production of *Test Targets 8.0*

The PRO for the cover specifies how Heidelberg SM74 sheet-fed offset press prints the cover using the MetalFX printing technology. The first section of the PRO documents the name of the project, a brief description of the project, who's responsible, the date of the press run, etc. The next section of the PRO describes digital contents, how these digital contents are imposed in relation to the press sheet. Printing specifications, e.g., press, press consumables, ink, follow. The last section of the PRO specifies paper quantity supplied, the number of impressions required, ink sequence, aqueous coating, and printing aim points.

The PRO for the body of the *Test Target 8.0* describes how Heidelberg SM74 sheet-fed offset press prints the bulk of the publication. The major differences between the cover and the text are that (1) text stock is used to print the body, (2) no aqueous coating is necessary for text stock, and (3) there are many 8-page signatures to be printed. There are also special cases to consider, e.g., a Test Form

needs to be printed with two CMYK ink sequences (KCMY and CMYK). This requires that we make two black plates that are to be printed in the first and the fifth printing unit. Another Test Form section of the signature needs to be printed with two spot colors in two different ink sequences. This means that the pressman has to wash up the printing units and place the required inks before he can print again. To make clear where these pages/signatures locate, it is paramount that an imposition plan is included to show the breaks for signatures, printing process, and collating sequences, etc. The use of blank pages may be necessary to bridge the gap since we want to begin a section from the right-hand side of the page.

We take advantage of the seven-unit HP Indigo 5500 digital press to demonstrate how multi-color ICC profile works in non-CMYK pictorial color image reproduction. The PRO for the Gallery of Visual Interest specifies what spot-color inks are needed in addition to its standard CMYK inks. The signature sequence between SM74 and HP Indigo has to be just right in order to accommodate the correct flow of the entire publication contents.

### Conclusion

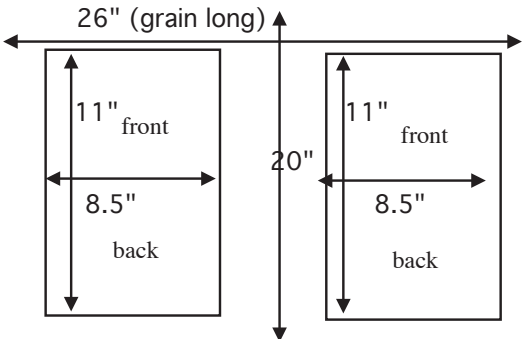
Press Run Organizer is a way for us to manage all the logistics of putting a publication together. We provide the specifics of the ink-paper-press conditions. We give extra attention to imposition details. We happened to make the imposition task harder by using two printing processes with some signatures printed with silver ink to have the MetalFX effect and others with spot colors to study ink trapping. Once we figure out the solution, PRO provides a detailed record of the printing and publication 'game plan' so that all parties have the same understanding, move towards the same goal. In short, Press Run Organizer is a useful tool that help us to plan, document, and communicate.

# Press Run Organizer: TT\_8 Cover

Project leader(s): Bob Chung & Franz Sigg  
 Telephone No: 475-2722 (o)  
 Today's date/time: 10/22/08

Prinerger; (3) print to specifications (up to 3 spot colors) using Heidelberg SM 74; (4) ship 4,000 for bindery.

Product description: Cover printed by SM74; ten 8-page signatures of text printed by SM74; three 4-page signatures of GVI by HP Indigo; die score and Smyth sewn binding; trimmed to final size 8.5" x 11"; send 4,000 to bindery; quantity delivered: 3,500

Job Specifications	Production Notes / Quality Assurance
<b>PREPRESS</b> (pick up TT8 InDesign file & modify) Contents: 1-up: Front & back cover + type on spine; 1-up: spot color inserts Color control bar: n/a	Notes on digital workflow: Paginated as reader's spread in InDesign CS3; PDF/X-1a using Prinerger PPD and JobOptions as single page; Impose in Preps according to the imposition layout Make sure 1/8" bleed is included in pagination; spine 7/32"
<b>PROOF</b> Manufacturer: <u>Kodak VLF Quantan 5080</u> Brand: <u>hp designjet 5500 ps</u>	Note on imposition: (Consult Press Run Organizer -- TT8 Body)
<b>RIP/PLATE</b> Kodak Prinerger 4; 175 lpi AM Manufacturer: <u>Kodak VLF 2400 dpi</u> Brand: <u>KPG(12mil); thermal Gold</u> late exposure guide: <u>gN6BR3u</u>	
<b>PRESS</b> Manufacturer: <u>Heidelberg sheetfed offset press</u> Brand: <u>Heidelberg 6-color SM 74</u> Size (max): <u>20'x29' (max)</u>	Notes on RIP and screening: RIP: <u>Creo Normalizer JTP; PS Version: 3011.104</u>
<b>FOUNTAIN SOL'N</b> Manufacturer: <u>3% Alkaless 3000 +</u> Brand: <u>3% Prisco 2451 per gallon</u> pH/Conductivity: <u>pH 4.5 buffered; Conduct. 2100</u>	Notes on standardized platemaking: Plate dot is equal to digital dot on the color control bar. Use CCDot meter or 1 x 1 checkerboard to verify plate dots
<b>BLANKET</b> Manufacturer: <u>Day International 3000</u> Brand: <u>Patriot</u> Packing: <u>0.006" over bearer (all units)</u>	Production schedules: Cover press run by SM74 Body by SM74 GVI by HP Indigo Bindery by Riverside: Wed., Oct. 30, 2008 Finished book delivery: Wed., Nov. 12, 2008 PIC Fall Meeting: Mon., Nov. 17-19, 2008
<b>INK</b> Manufacturer: <u>Kohl &amp; Madden CMYK</u> & MFX Metalstar Silver (S) Ink Order: <u>SCMYK</u>	Press Date Oct. 16, 2008 Oct. 27-29, 2008 Oct. 17-23, 2008
<b>PAPER</b> Quantity: <u>2,500</u> Brand: <u>Sappi McCoy</u> Basis weigh / Size: <u>100# gloss cover, 20x26, grain long</u>	Distribution: *Paper donor (Sappi / Dave Niles) 200 PIC members 100 x 12 = 1,200 RIT/Sloan 200 RIT/PAL 400 CMS Partners (X-Rite, Alwan, CHROMiX) 100 ea. RIT/SPM 1,200
<b>PRINTING</b> Reference: Ink-down sequence: <u>SKCMY + acq. Coating</u> *Solid ink density: <u>K: 1.75 M: 1.40</u> ( $\pm 0.10$ ) <u>C: 1.35 Y: 1.00</u> <u>S: 0.45</u> <b>Status T: visual filter</b>	
<b>ADDITIONAL NOTES</b> Run Cover 2 up. Send 4,000 to the bindery. Gutter: 0.25" Proof Date: Monday, October 13, 2008	

# Press Run Organizer: TT\_8 Body

Press date: **Oct. 27-29, 2008**

Project description: **Test Targets 8.0 Body**

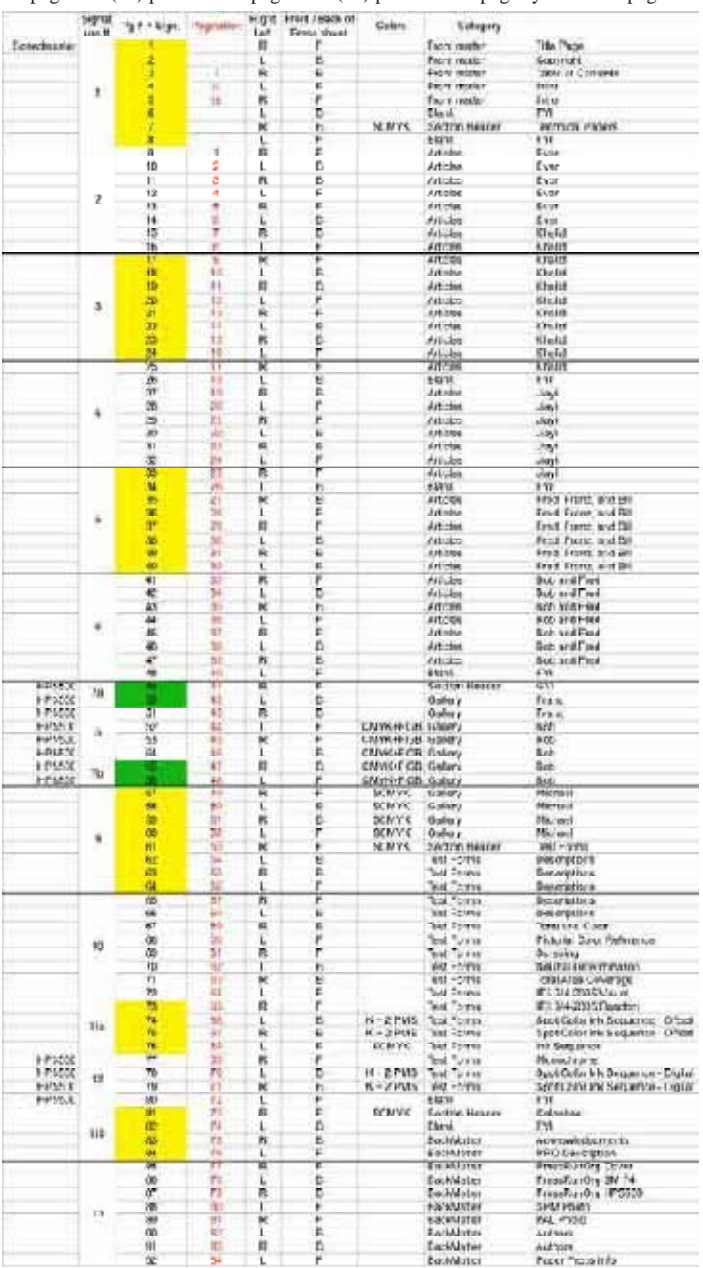
Project leader(s): **Robert Chung & Franz Sigg**

Telephone No: **475-2722**

Today's date/time: **10/22/08**

Printing description: (1) Prepare publication text using InDesign CS3; (2) prepare CtP with 175 lpi AM screening by Kodak Prinergy; (3) print to specifications using Heidelberg Speedmaster 74.

Product description: Cover printed by SM74; ten 8-page signatures of text printed by SM74; three 4-page signatures of GVI by HP Indigo; die score and Smyth sewn binding; trimmed to final size 8.5" x 11"; send 4,000 to bindery; quantity delivered: 3,500

Job Specifications		Production Notes / Quality Assurance	
<b>PREPRESS</b>	Print on both sides	Ten 8-page text (80) plus three 4-page GVI (12) plus 4 cover pages yields a 96-page book.	
Signature contents:	(see description at right)		
Image resolution:	300 ppi		
Color control bar:	RIT Color Control Bar plus local color bar		
<b>PROOF</b>			
Manufacturer:	Kodak VLF Quantan 5080		
Brand:	hp designjet 5500 ps		
<b>RIP/PLATE</b>	Kodak Prinergy 4; 175 lpi AM		
Manufacturer:	Kodak VLF 2400 dpi		
Brand:	KPG(12mil); thermal Gold		
Plate exposure guide:	gN6BR3u		
<b>PRESS</b>			
Manufacturer:	Heidelberg sheetfed offset press		
Brand:	Heidelberg 6-color SM 74		
Size (max):	20'x29' (max)		
<b>FOUNTAIN SOLUTION</b>			
Manufacturer:	3% Alkaless 3000 +		
Brand:	3% Prisco 2451 per gallon		
pH/Conductivity:	pH 4.5 buffered; Conduct. 2100		
<b>BLANKET</b>			
Manufacturer:	Day International 3000		
Brand:	Patriot (77 mil, 4 ply, compressible)		
Packing:	0.006" over bearer (all units)		
<b>INK</b>	Process color		
Manufacturer:	Kohl & Madden		
Note:			
Temp./Tack:			
<b>PAPER</b>	Quantity: 44,000		
Brand:	<b>Sappi McCoy</b>		
Basis weight / Size:	100# gloss text, 19x25, grain long		
<b>PRINTING</b>	Reference:		
Ink-down sequence:	Silver + KCMY + 1788C + 7466C		
SID (wet):	<b>Silver: 0.45</b>		
(±0.10)	<b>K: 1.75 M: 1.40</b>		
	<b>C: 1.35 Y: 1.00</b>		
	<b>P1788: 1.47 P7466: 1.19</b>		
<b>AD. NOTES</b>	See Imposition page for signature reference.		
Silver Signatures	<b>1, 9</b>		
KCMYK Signatures	<b>11</b>		
1788 + 7466 Sign.	<b>11</b>		
<b>ICC PROFILE</b>	ISO Standard		
<b>PAPER</b>	Sheet Size: 19 x 25, grain long 4400 (incl. MR and overage)/signature x 10		
<b>SAMPLING</b>	Pull 10 sheets of each signature after correct color has been reached.		



# Press Run Organizer: TT\_8 Gallery of Visual Interest

Press run date: Oct. 17-23, 2008  
 Project description: Test Targets 8.0 GVI  
 Project coordinators: Bob Chung & Franz Sigg  
 475-2722 (o)  
 Today's date: 10/22/08

Objectives: (1) Content preparation for Test Targets 8.0 using HP Indigo

Notes: Product description: Cover printed by SM74; ten 8-page signatures of text printed by SM74; three 4-page signatures of GVI by HP Indigo; die score and Smyth sewn binding; trimmed to final size 8.5" x 11"; send 4,000 to bindery; quantity delivered: 3,500

Job Specifications		Production Notes / Quality Assurance
<b>TEST FORM</b> Number: <b>7, 8, 12</b> Descriptions: Forms based on the needs of the form creator. Image resolution: Form dependent	Notes: Form_1: Signature 7; GVI Form_2: Signature 8; GVI Form_3: Signature 12; Spot Color Overprint	
<b>PAGINATION</b> Software: InDesign CS3 Dimension: 12" x 18" (305 mm x 460 mm) Color control bar: K+3C + 4C neutrals	Notes: <div style="border: 1px solid black; padding: 10px; margin-top: 10px;"> </div>	
<b>COMMUNICATION</b> File Submission Protocol: HTTP File Creation Procedure: TT8 PDF SOP Hard copy Proof: Yes		
<b>DFE</b> RIP manufacturer: Brand: Screening:		
<b>PRESS</b> Manufacturer: HP Brand: Indigo 5500 Colors: CMYK plus PMS 1788 & 7466 Pantone 032C(R); Hexgreen; 2925(B)	Notes: 600 x 600 spi Capable of duplex printing; simplex is used 100 impressions per min. per side QA: Standard photoconductor life	
<b>PAPER</b> Quantity: 12,000 Brand: <b>Sappi McCoy</b> Basis weight: gloss 100# text, 12x18 text, grain long Grain direction: Grain short	Notes: 12" x 18" (305 mm x 460 mm) 4,000/signature x 3	
<b>PRINTING</b> Reference: <b>HP Calibration</b> *Solid ink density: <b>C: 1.45 M: 1.45</b> ( $\pm 0.10$ ) <b>Y: 1.10 K: 1.75</b> <hr/> <b>P032: 1.15 P2925: 1.08</b> <hr/> <b>PHex: 1.22</b> <hr/> <b>P1788: 1.32</b> <hr/> <b>P7466: 1.22</b>	Notes: Color Orders: Form 1-2: CMYK R(32C), G(Hex), B(2915) Form 3: CMYK 1788, 7466	
<b>SAMPLING</b>	Pull 10 sheets of each signature after correct color has been reached.	
<b>ADDITIONAL NOTES</b>		

# School of Print Media



Pictured from left to right, listed from top to bottom:

**Franz Sigg**

*Faculty / Steering Committee / Author*

**Jiayi Zhou**

*Project Coordinator / Author*

**Edline Chun**

*Faulty / Steering Committee / Editor*

**Stephanie Pieruccini**

*Project Coordinator*

**Khalid Akhter Husain**

*Author*

**Pat Sorce**

*SPM Administrative Chair / Executive Committee*

**Robert Chung**

*Faulty / Executive and Steering Committee / Author*

**Evan Anderson**

*Author*

**Michael Riordan**

*Faulty / Steering Committee / Author*

# Printing Applications Laboratory



Pictured from left to right, listed from top to bottom:

**John Detmer**  
*Digital Systems Technologist*

**Jeremy Vanslette**  
*Digital Lab Manager*

**Barbara Giordano**  
*Operations Manager*

**Dan Gramlich**  
*Sheetfed Press Operator*

**Josh Messing**  
*Digital Print Technologist*

**Bill Garno**  
*PAL Director / Executive and Steering Committee*

**Fred White**  
*Press Operations Manager*

**Not Pictured:**  
**Brian Waltz**  
*Digital Print Technologist*

**Andrew Henry**  
*Digital Systems Technologist*

**Fred Hsu**  
*Color Specialist / Steering Committee / Author*

## Author Biographies



### **Robert Chung, Gravure Research Professor**

Robert Chung is a professor in the School of Print Media, Rochester Institute of Technology. Bob teaches courses in printing process control and color management. He has published over 60 technical papers. Bob was named RIT Gravure Research Professor in 2004. He is the recipient of the 2007 Educator of the Year Award from the Electronic Document Systems Foundation (EDSF); the 2007 Fedrick D. Kagy Life Achievement Award from the International Graphic Arts Education Association (IGAEEA); the 2006 Michael H. Bruno Award from the Technical Association of the Graphic Arts (TAGA); and the 1991 Education Award of Excellence from the Graphic Arts Technical Foundation (GATF).

Contact: [rycprr@rit.edu](mailto:rycprr@rit.edu)



### **Fred Hsu, Color Specialist**

Fred is a Color Specialist for RIT's Printing Applications Lab since 2003. Through his research at RIT, Fred has specialized in printer calibration and optimization, color management workflow, and process control. He also provides CMS implementation training in PAL color management seminars. Fred holds an M.A. in Graphic Communications from New York University and M.S. in Printing Technology from RIT.

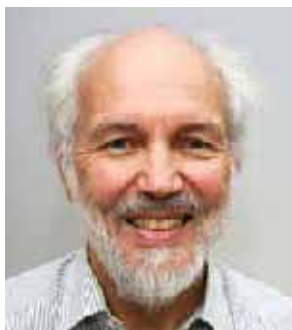
Contact: [cyhter@rit.edu](mailto:cyhter@rit.edu)



### **Michael Riordan, Assistant Professor**

Michael Riordan is an Assistant Professor at RIT's School of Print Media where he teaches coursework relating to color, premedia, and print production workflows. Through his research at RIT, he specializes in streamlining workflow practices for print service providers and creative agencies to help assess and optimize their production environments. Michael holds a Master of Science in Graphic Arts Systems from the Rochester Institute of Technology.

Contact: [mprppr@rit.edu](mailto:mprppr@rit.edu)



### **Franz Sigg, Senior Research Associate**

Franz Sigg is a teacher, researcher, and thesis adviser to students at the School of Print Media at Rochester Institute of Technology. He holds a Master of Science degree in Printing Technology from RIT. He has spent much of his professional career developing, testing, and producing both analog and digital test targets for the graphic arts industry. Currently, he is involved in designing and programming PostScript targets for digital imaging systems. Recently Franz developed specialized test targets and test forms to help optimize and calibrate CTP systems, particularly for newsprint. Franz was the 1998 TAGA Honors Award recipient.

Contact: [fxsppr@rit.edu](mailto:fxsppr@rit.edu)



## Author Biographies



### **Evan Andersen, Graduate Student**

Evan Andersen received a Bachelor of Science degree in Imaging and Photographic Technology from Rochester Institute of Technology in 2007. After being exposed to the printing industry and color management through two summer internships at Pantone, Inc., he has been pursuing those interests in graduate school. He is currently in his second year at RIT's School of Print Media. For his thesis, he is working to evaluate the image quality and color management of fine art reproduction workflows within U.S. cultural institutes.

Contact: [etandersen@gmail.com](mailto:etandersen@gmail.com)



### **Jiayi Zhou, Graduate Student**

Jiayi Zhou is currently a second-year graduate student in School of Print Media at RIT with a concentration in Color Science. She received her Bachelor of Print Technology from Tianjin University of Science and Technology (TUST). During her undergraduate cooperative education experience, Jiayi was involved in web-to-print and self-publishing business. Now she is doing her third co-op as a coordinator of the *Test Targets 8.0* project. Jiayi's graduate research focuses on color management in various printing workflows and how people perceive color differences.

Contact: [zxj7306@rit.edu](mailto:zxj7306@rit.edu)



### **Khalid Akhter Husain, Graduate Student**

Khalid Akhter Husain is a graduate student in the School of Print Media at RIT. His major concentration is printing technology, while packaging science is his minor concentration. His major interest is color management research related to spectral-based color reproduction and multi-ink printing. Khalid has a Bachelor's Degree in Electrical and Computer Engineering from New Jersey Institute of Technology.

Contact: [kah2227@rit.edu](mailto:kah2227@rit.edu)



### **Bill Pope, Technical Director of Flexographic Technical Association**

Bill is the Technical Director for the Flexographic Technical Association where he provides technical leadership and support for the association's educational objectives. Prior to the FTA Bill worked for nine years at RIT. There he served as the Technical Manager of PAL and adjunct faculty at the School of Print Media. He also served as an instructor for various industry education programs. Prior to RIT, he worked for ten years in folding carton packaging as a process engineer focused on print quality, productivity improvements, and technology implementations including computer-to-plate and closed-loop color control. He received his Bachelor's degree in Printing Systems and Engineering from RIT in 1990. Bill has been and is active with a variety of organizations including TAGA, NAPL, WOA, CGATS, TLMI, and IDEAlliance's Print Properties Committee and is a regular presenter at various industry events.

Contact: [bpope@flexography.org](mailto:bpope@flexography.org)



Cover printed at RIT's Printing Applications Laboratory on the Heidelberg Speedmaster 74 Sheetfed Press with Sappi McCoy 100# Gloss Cover.

Body printed at RIT's Printing Applications Laboratory on Sappi McCoy 100# Gloss Text on the Heidelberg Speedmaster 74 Sheetfed Press.

Pages 41-48 and 69-72 printed on the Hewlett-Packard HP Indigo5500 Digital Press.